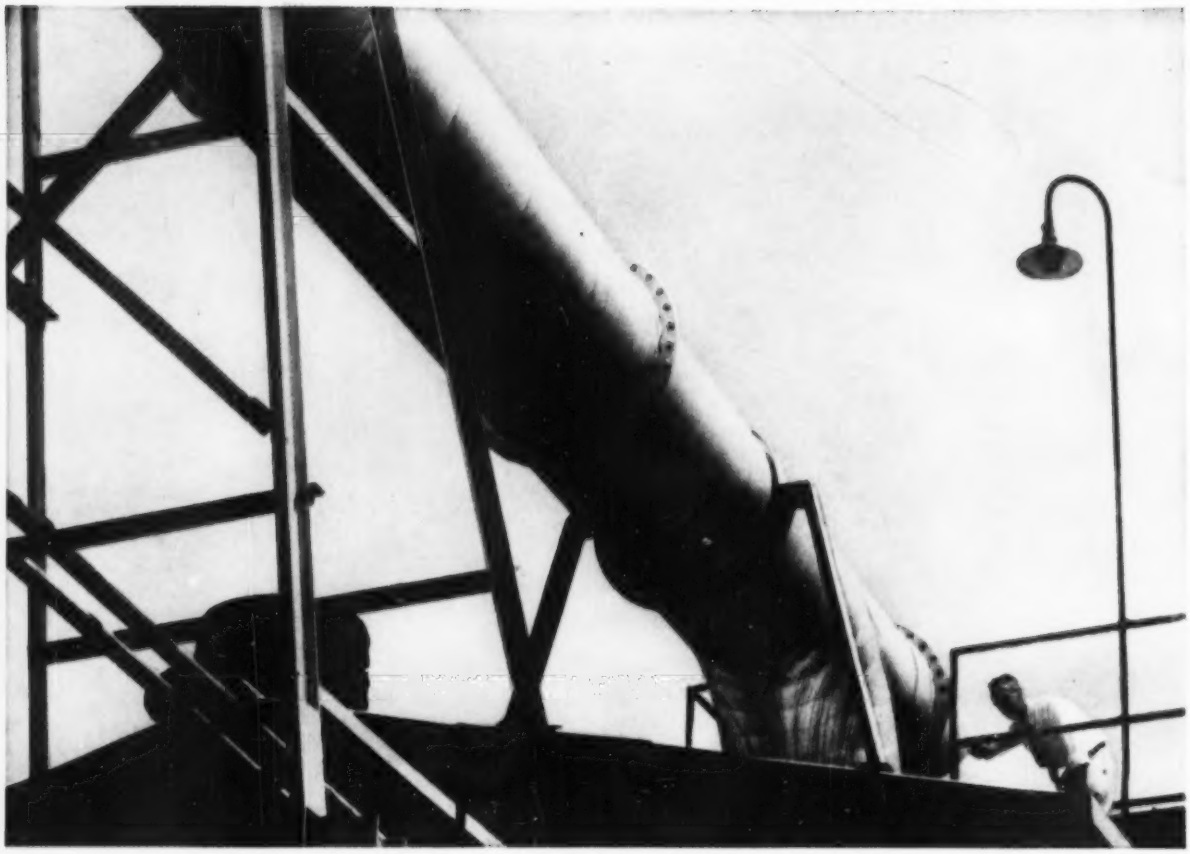
JULY 1953

Chemical Engineering Progress

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS



A "COLUMBIA" *Activated Carbon Solvent Recovery Plant . . .*

Trade-Mark

. . . at the end of this duct is saving this man thousands of dollars a year. His installation is one of the many that save industry more than $150,000,000 annually by recovering over *2 billion* pounds of solvent vapors!

COLUMBIA Activated Carbon solvent recovery plants are used in a variety of industries—plastics, rubber, synthetic fibers, smokeless powder, rotogravure printing, lacquer coating, and many others where solvents are vaporized.

Alcohols, esters, ethers, ketones, hydrocarbons, chlorinated compounds, and practically all mixtures of these or other low-boiling solvents are recovered efficiently and economically.

EFFICIENCY OF RECOVERY: 90%+ of the solvent vapor that reaches most plants is recovered.

COST OF RECOVERY: Less than 0.5¢ per pound of solvent, in many cases.

If you vaporize solvents in your process, let us help you. We can design and supply a complete solvent recovery system to fit your specific requirements.

Write today for our booklet "How 7 Industries Saved $150,000,000 a Year with COLUMBIA Activated Carbon," Form 6658.

CARBIDE AND CARBON CHEMICALS COMPANY

A Division of
Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.

COLUMBIA
Activated Carbon

SOLVENT RECOVERY · CATALYSIS
GAS AND AIR PURIFICATION

The term "Columbia" is a registered trade-mark of Union Carbide and Carbon Corporation

Chemical Engineering Progress

JULY, 1953

Volume 49, No. 7

Editor: F. J. Van Antwerpen

OPINION AND COMMENT

331 ARE YOU GETTING YOUR NICKEL'S WORTH?
George F. Jenkins

ENGINEERING SECTION

333 MANUFACTURE AND DISTRIBUTION OF CARBON DIOXIDE
H. A. Sommers

340 PULSE COLUMNS
Richard Stephenson

341 MIXED-BED ION EXCHANGE Part I
Joseph Thompson, Francis X. McGarvey, John F. Wantz, S. F. Alling, M. E. Gilwood, and David R. Babb

349 THERMODYNAMICS OF AMMONIA SYNTHESIS AND OXIDATION
R. H. Harrison and K. A. Kobe

354 CALCULATION OF LEACHING OPERATIONS
E. G. Scheibel

359 EXPERIMENTAL REACTION RATES IN SYNTHESIS OF AMMONIA
R. M. Adams and E. W. Comings

367 RESISTANCE AND COMPRESSIBILITY OF FILTER CAKES Part II
H. P. Grace

378 DESIGN OF A ROTARY DRIER
G. Gutzeit and J. R. Spraul

387 HEAT-TRANSFER ABSTRACTS
"C.E.P." SYMPOSIUM SERIES NO. 5

388 TECHNICAL COMMENT ON "EVAPORATION FROM DROPS"
Hans Tonn

390 PLASTICS CEMENT REFERENCE SHEET
R. B. Seymour and R. H. Steiner

NEWS

17 EARNINGS OF A.I.Ch.E. MEMBERS
29 INDUSTRIAL NEWS
SODA ASH PLANT IN WYOMING
36 MARGINAL NOTES
41 DATA SERVICE
50 A.I.Ch.E. CANDIDATES
54 SECRETARY'S REPORT
69 LOCAL SECTIONS
70 FUTURE MEETINGS
73 NEWS ABOUT PEOPLE
76 CLASSIFIED
78 NECROLOGY
80 THE PRESIDENT SAYS . . .
W. T. Nichols

4 • 6 LETTERS TO THE EDITOR
10 • 12 • 14 NOTED AND QUOTED

Advertising Manager: L. T. Dupree

Publication Committee:
T. K. Sherwood, *Chairman*
F. J. Van Antwerpen
D. L. Katz
C. G. Kirkbride
D. S. Maisel
J. H. Rushton
L. P. Scoville

Publication Board:
C. G. Kirkbride, *Chairman*
G. E. Holbrook
L. P. Scoville
T. K. Sherwood
E. P. Stevenson
F. J. Van Antwerpen

Published monthly by American Institute of Chemical Engineers, at 15 North Seventh Street, Philadelphia 6, Pennsylvania. Editorial and Advertising Offices, 120 East 41st Street, New York 17, N. Y. Communications should be sent to the Editor. Statements and opinions in *Chemical Engineering Progress* are those of the contributors, and the American Institute of Chemical Engineers assumes no responsibility for them. Subscriptions: U. S. and possessions, one year $6.00; two years $10.00 (Applies to U. S. and possessions only.) Canada $6.50; Pan American Union, $7.50; Other Foreign, $8.00 Single Copies of *Chemical Engineering Progress* older than one year cost $1.00 a copy; others are 75 cents. Entered as second class matter December 9, 1946, at the Post Office at Philadelphia, Pennsylvania, under Act of August 24, 1912.

Copyright 1953 by American Institute of Chemical Engineers.

Member of Audit Bureau of Circulations. *Chemical Engineering Progress* is indexed regularly by Engineering Index, Incorporated.

For Laboratory Testing and Pilot Plant Runs—
Compact, Efficient SIFTER

Carrier Platform for Flask Agitation Can Be Mounted on Same Base!

Here's a compact, practical unit for pilot plant and experimental work. The all-metal Gump Laboratory Sifter gives *big* capacity for its size. Heavy-duty drive base imparts a uniform rotary motion on a true level plane, to every inch of sieve surface. All parts are readily accessible for easy cleaning.

The same drive unit does an excellent job on flask agitation and aeration of control samples in chemical analysis. Flask carrier platform can be easily and quickly interchanged with Sifter box, for the laboratory that wants *both* operations. Available with both Sifter box and flask platform, or with either one—and in several sizes. *Write for details and recommendations on your specific problems.*

B. F. GUMP CO.,
1311 So. Cicero Ave., Chicago 50, Ill.

Gentlemen: Please send me descriptive literature and complete information on the GUMP-Built Equipment indicated below:

☐ GUMP Laboratory Sifter and Flask Agitator.
☐ DRAVER FEEDERS—accurate volume percentage feeding.
☐ DRAVER Continuous Mixing Systems—accurate, efficient mixing.
☐ VIBROX PACKERS—pack dry materials in bags, drums, barrels.
☐ NET WEIGHERS—automatic weights range from 3 oz. to 75 lbs.

B. F. GUMP CO.
Engineers and Manufacturers Since 1872

Gump
1311 SOUTH CICERO AVE.
CHICAGO 50, ILLINOIS

for *Low*
VACUUM PUMP MAINTENANCE COSTS and BETTER VACUUM . . .
it's the
HILCO OIL RECLAIMER
for VACUUM PUMP USERS . .

Oil Reclaimer

A simple, economical and efficient method of restoring contaminated lubricating and sealing oil to the full value of NEW OIL. The HILCO will produce and maintain oil free of solids, gums, water and gases in a continuous, all-electric, automatic operation.

Be SURE of clean oil in your HIGH VACUUM PUMPS

HILCO OIL RECLAIMER SYSTEMS . .

• *WRITE FOR COMPLETE DETAILS IN THE FREE BULLETIN*

Recommendations at no Obligations

THE HILLIARD CORPORATION
PURIFIER DIVISION
144 W. Fourth St., Elmira, N. Y.

HILCO — For Reclaiming, Filtering, Purifying and Re-Refining Oil

IN CANADA — UPTON - BRADEEN - JAMES, Ltd.
990 Bay St., Toronto, 3464 Park Ave., Montreal

LETTERS TO THE EDITOR

Sherwood Number

For many years the dimensionless group hl/k has been designated as the Nusselt number (*1*). This, along with an increasing series of other dimensionless groups, has proven useful to the engineer. In the field of material transfer, Sherwood (*2*) and others have found occasion to use an analogous dimensionless group, ml/D_v, which does not appear to have been assigned an appropriate name. It is suggested that this dimensionless group be given the name "Sherwood number" in recognition of Professor Sherwood's outstanding contributions to the field of material transfer.

On the basis of the foregoing, the Sherwood number could be defined by either of the following dimensionless groups:

$$Sh = \frac{ml}{D_{F,k}} = \frac{ml}{D_{v,k}} = \frac{mlP}{D_{M,k}} \qquad (1)$$

As an example, in evaporation from a drop by diffusion into a quiescent perfect gas, the Sherwood number assumes (*3*) the following form, and the numerical value shown in the case of a spherical surface:

$$Sh = \frac{m^*_k b_k T}{2\pi r_d D_{M,k} \ln \dfrac{n'_{1,s}}{n'_{1,\infty}}} = 2 \qquad (2)$$

The Sherwood number as utilized above is equivalent to the Nu' employed by Ranz and Marshall (*3*).

Notation

b_k = specific gas constant of component k, ft./° R.

$D_{F,k}$ = Fick diffusion coefficient of component k, sq.ft./sec.

$D_{M,k}$ = Maxwell diffusion coefficient of component k, lb./sec.

$D_{v,k}$ = volumetric diffusion coefficient of component k, sq.ft./sec.

h = thermal transfer coefficient, B.t.u./(sq. ft.)(sec.)(° F.)

k = thermal conductivity, (B.t.u.)(ft.)/(sq. ft.)(° F.)(sec.)

l = characteristic length, ft.

ln = natural logarithm

m = material transfer coefficient, ft./sec.

m^*_k = transport rate of component k, lb./sec.

$n'_{1,s}$ = mole fraction of stagnant component at interface

$n'_{1,\infty}$ = mole fraction of stagnant component at a distance from interface

P = pressure, lb./sq.ft.

r_d = radius of drop, ft.

Sh = Sherwood number (Nu' in Ranz and Marshall notation)

T = temperature, ° R.

Literature Cited

1. McAdams, W. H., "Heat Transmission," McGraw-Hill Book Co., Inc., New York (1942).
2. Sherwood, T. K., and R. L. Pigford, "Absorption and Extraction," McGraw-Hill Book Co., Inc., New York (1952).
3. Ranz, W. E., and W. R. Marshall, Jr., *Chem. Eng. Progress*, **48**, 141 and 173 (1953).

B. H. Sage,
Professor of Chemical Engineering, California Institute of Technology, Pasadena, Calif.

Who is an Engineer?

. . . Although the editor is on firm ground in pointing out a somewhat ridiculous result stemming from E.J.C.'s attempt to incorporate in New York State ("C.E.P.", Opinion and Comment, May, 1953), a few of his statements appear naive. . . . I refer in particular to the symposium Engineering Licensing ("C.E.P.", April, 1950) and the discussion thereof (May, 1950, p. 211).

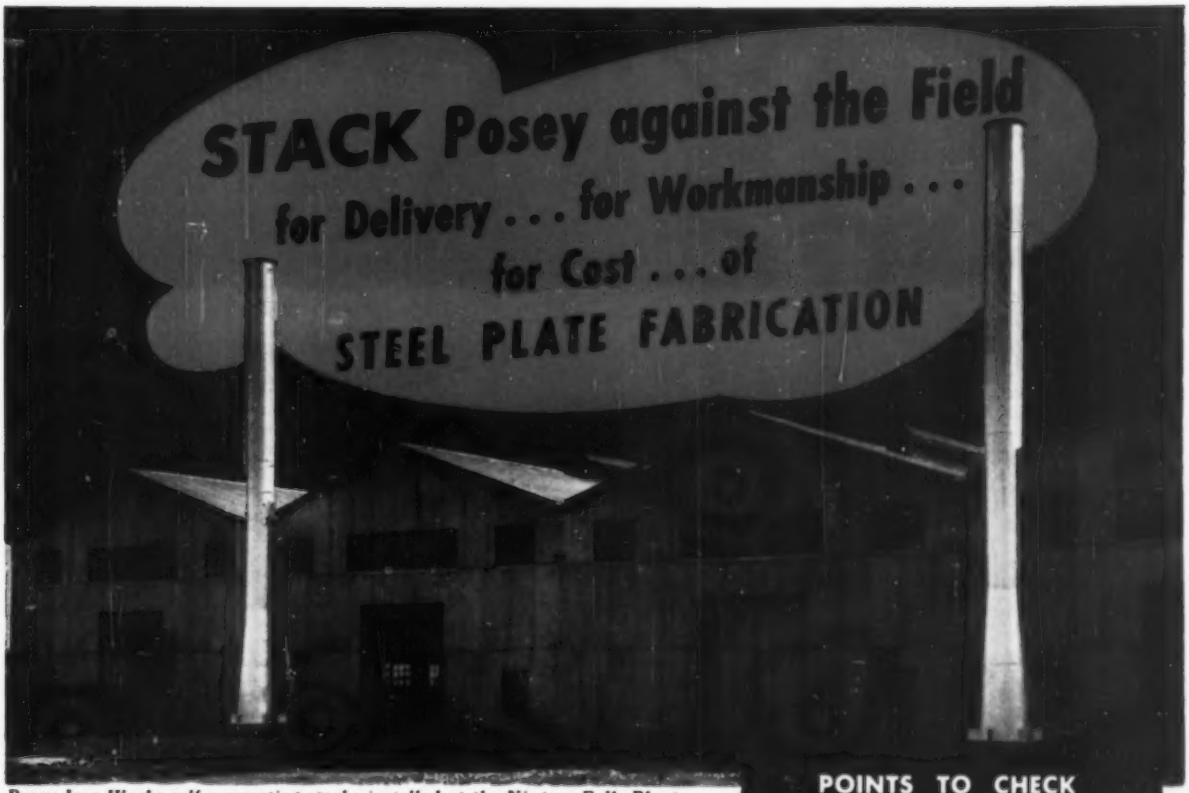
Your editor states, "How such a law ever got past the engineering societies is a mystery to us, but there it is being used to prevent legitimate, benign, collaboration of the engineering societies." Yet in the symposium (pp. 168-170) J. F. Fairman gives a clear picture of how such laws are passed. . . . There is no mystery as to how these laws are passed. They are drafted, introduced, and lobbied by engineers, professional engineers, prominent engineers, yes, even chemical engineers. The pill is doubly bitter when one society amongst our pyramid of interlocking memberships is brought forward and "judged" by those standards so firmly advocated by another society.

Again, your editor asks, "which definition is to be master, the legal or the historical?" and later on he states, "—nor did it (the law) give to the licensing societies exclusive ownership to the word *engineer*." Yet all three members of the symposium were pointed in their remarks to the effect that *nonprofessional* engineers were stopped from advertising, discredited when testifying, and actually precluded from collecting fees.

Holbrook makes the most definite statement—"The laws of 48 states and all the provinces of Canada tell us who is an engineer. He is one legally qualified to practice his profession."

By a strange coincidence, both volumes quoted above contain discussions of the A.I.Ch.E. Admissions Committee. I am one of those numerous Junior members who,

(*Continued on page 6*)



Posey Iron Works self supporting stacks installed at the Niagara Falls Plant of the International Graphite & Electrode Division of Speer Carbon Co. Height: 50 ft. Diameter: 3 ft.

Posey Iron is really "stackin' 'em up" for industries large and small. Stack buyers find that stacks by Posey Iron are sound in workmanship . . . competitive in cost . . . and delivered on date of promise.

Whether for stacks . . . tanks . . . pressure vessels . . . pipe . . . or digesters . . . steel plate fabrication by Posey Iron meets all standard codes including ASME; API-ASME; API.

Posey Iron does the complete job . . . design . . . fabrication . . . erection. 16½ acres of plant under roof promote smooth flow of production. Shipping is facilitated by favorable location in a key rail and road center — Lancaster, Pa.

Stack Posey Iron against the field on your next stack job. Our estimate puts you under no obligation.

POINTS TO CHECK BEFORE YOU BUY STEEL PLATE CONSTRUCTION

1. Has supplier adequate plant to produce job without costly fumbling and delays?
2. Will supplier assign to your job designers and executives with experience in your field?
3. Have you checked with business acquaintances as to the supplier's reputation for sound workmanship?

Posey Iron WELCOMES requests for further information.

AND STEEL AND ALLOY STEEL PLATE FABRICATION

POSEY IRON WORKS, INC.

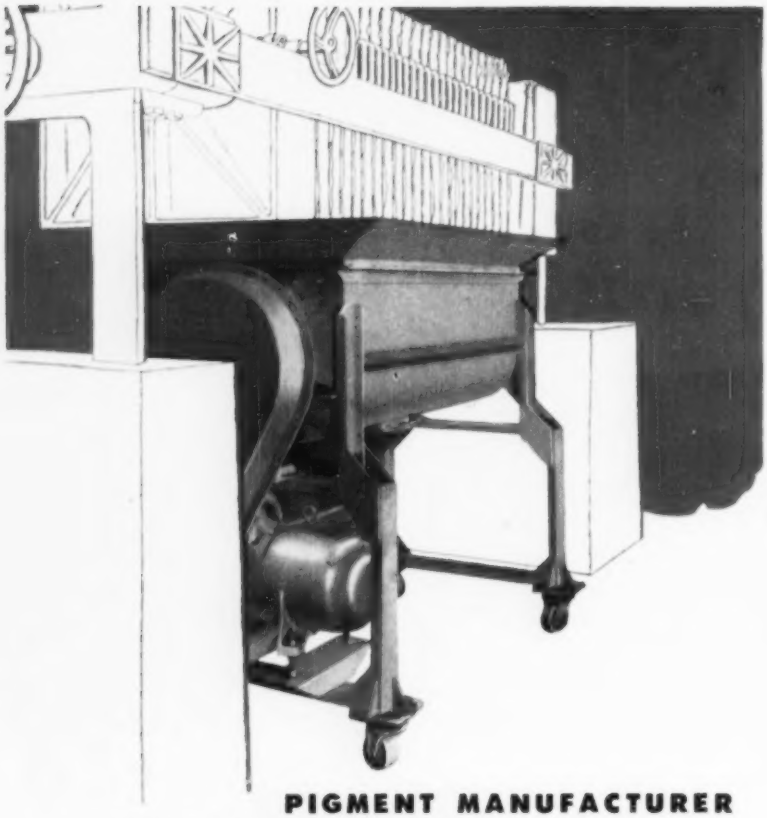
Steel Plate Division

LANCASTER, PA.

New York Office: Graybar Building

ESTABLISHED SINCE 1910

DIVISIONS
Brick Machinery
Foundry
Industrial Heating
Iroquois
Shipbuilding
Steel Plate



PIGMENT MANUFACTURER BREAKS PRODUCTION BOTTLENECK WITH READCO MIXERS

A large producer of water soluble paint pigments faced a problem confronting many management men . . . how to get more production—in a hurry.

In an analysis of his process, a bottleneck was found. Pigment solids were being removed from the emulsion in filter presses. Unmanageable filter cake was being scraped from the presses and shoveled into drums, a costly, time-consuming process.

A series of laboratory tests pointed out the simple solution. A battery of Readco Spiral Ribbon Mixers was installed beneath the presses. These mixers reduce the cake into a homogeneous, semi-liquid mass, ready for shipment. Processing time and costs have been greatly reduced.

You can approach your production problems in the same way. The Read Standard Corporation not only manufactures a broad line of chemical processing equipment, it offers you the services of its engineering specialists and laboratory facilities to assist you in the solution of your special processing problem.

READ STANDARD
CORPORATION

BAKERY-CHEMICAL DIVISION, York, Pennsylvania—Los Angeles 39, California

LETTERS TO THE EDITOR

(Continued from page 4)

at 35, must face the judgment of my peers. Since I am now working exclusively with patents, after only a short three years as a true chemical engineer, I fear that I shall be found wanting. True, I probably am not a chemical engineer at present. Certainly, I fall short of A.I.Ch.E.'s definition. Thus, when that day arrives I shall either be forced into the non-voting, dues-paying limbo known as associate membership or shall quietly be dropped from the lists. The Secretary's report for April notes that sixty-one such memberships were discontinued because "they had neither accepted *automatic* transfer to Associate membership nor had they applied for Active membership." Possibly they preferred the quiet way rather than embarrass their friends who must be listed as references. . . . The chairman of the Admissions Committee attempts to be quite stern with those references who fail to supply adequate information. Could it be that these references prefer not to "judge"? Certainly, the chairman implies that it is quite distasteful to hold a "special investigation." Maybe he too shrinks from "judging."

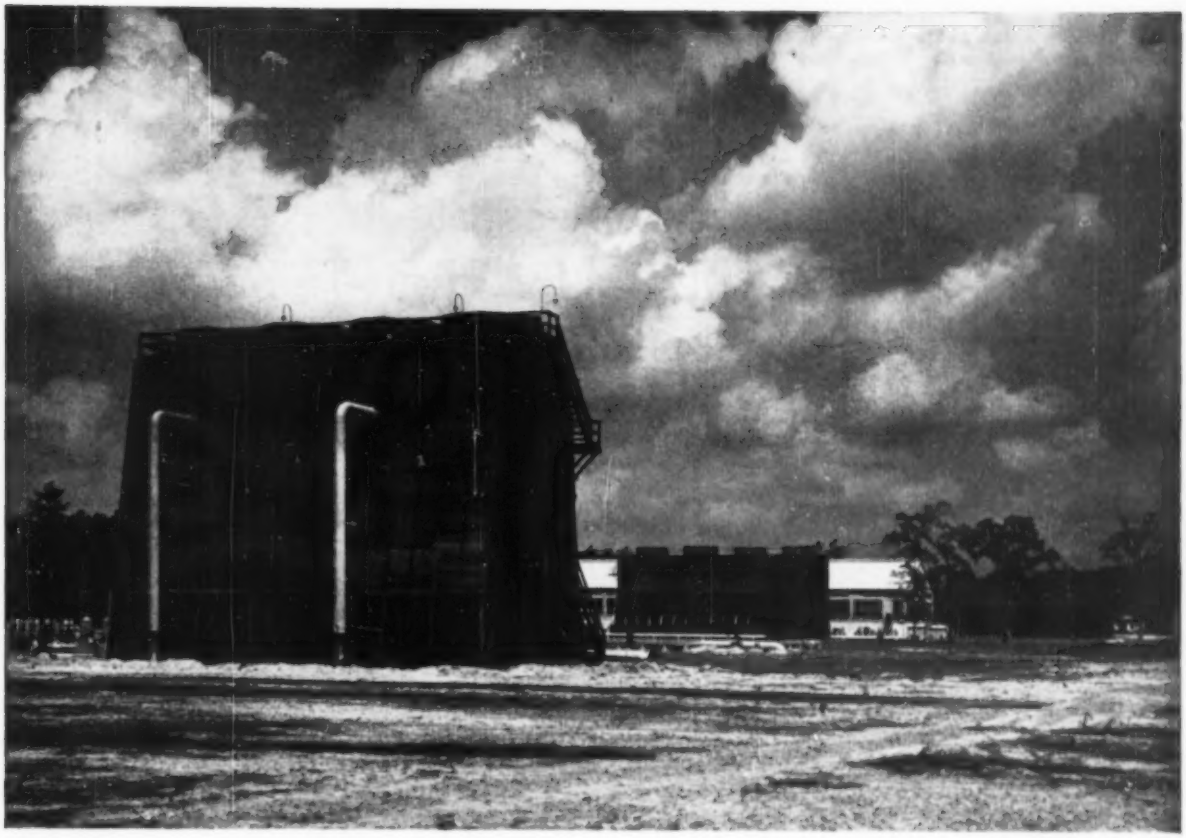
Should my present study of law be successful, I hope that the day never arrives that I am forced to cross-examine a brother chemical engineer with an outstanding reputation yet known not to hold a license, and possibly not even to meet the requirements of an active chemical engineer. Would I ask "those" questions? I can only hope the case might not be that important. . . . I could not help noticing the bitter editorial attack on the results of the professional engineer's attempt to judge other engineers, and in the same issue the Admissions Committee's plea that all members should step forward willingly to judge one another.

Most men hesitate to judge. A magazine should be careful lest it judge without full knowledge of the facts.

L. L. MAHONE,
Patent Dept., Victor Chemical Works, Chicago, Ill.

∫ We knew of "C.E.P.'s" prior symposia, mentioned it in parts of editorial cut for space reasons . . . also quoted recent survey of A.I.Ch.E. members, only 28% licensed, of which 26% felt it of any value . . . this means 7% of our members think licensing of importance to their work . . . we still feel licensing only gives right to practice publicly; does not give exclusive use of the word to the associations of licensed engineers . . . laws which are "drafted, introduced, and lobbied by engineers" need, like all laws, to be based on justice. . . .

EDITOR.



RE-ORDERS . . .

Bulletins on HUDSON TOP PERFORMANCE cooling equipment mailed upon request.

The three cooling towers pictured above are a part of EIGHTY large Hudson cooler installations made by a gas transmission company—installations involving HUDSON cooling towers, atmospheric sections and HUDSON Solo-aire units made in eight different states from Texas to New York.

The fine performance, low operating cost, mechanical excellence, and good business relations experienced by buyers of Hudson equipment, make Hudson the favored supplier when additional installations are considered. Over SEVENTY-FIVE PERCENT of Hudson cooling equipment now being manufactured will be installed for present users.

HUDSON
ENGINEERING CORPORATION
FAIRVIEW STATION • HOUSTON, TEXAS

B&W BULLETIN 6-F

Properties of Carbon, Alloy and Stainless Steel Tubing for High-Temperature and High-Pressure Service

The Story of the Croloys

New data contained in the seventh, revised edition of B&W's Technical Bulletin 6-F make it must reading for technical personnel concerned with the properties of tubing for high-temperature and high-pressure service. TB-6F contains up-to-the-minute information on:

- Requirements of Tubing for High-Temperature Service
- Influence of Alloying Elements
- Chemical Composition
- Room-Temperature Properties
- Short-Time Tensile Properties
- Stress-Rupture
- Creep
- Thermal Expansion
- Thermal Conductivity
- Impact Properties
- Microstructure—Transformation Temperatures
- Air-Hardening Properties
- Effect of Hydrogen
- Common Causes of Tube Failures
- Upset, Formed and Machined Tube-Ends

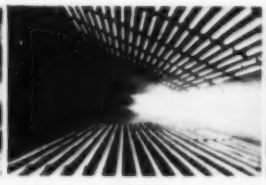
On such grades as

B&W	NOMINAL ALLOY CONTENT	MAXIMUM SERVICE TEMPERATURE
Carbon Steel (Killed)	——	1050F
Carbon-Moly	0.50% Mo	1050F
Croloy ½	0.60% Cr 0.50% Mo	1075F
Croloy 1¼	1.25% Cr 0.50% Mo	1100F
Croloy 2	2% Cr 0.50% Mo	1150F
Croloy 2¼	2.25% Cr 1.00% Mo	1175F
Croloy 3-M	3% Cr 0.90% Mo	1175F

B&W	NOMINAL ALLOY CONTENT	MAXIMUM SERVICE TEMPERATURE
Croloy 5	5% Cr 0.50% Mo	1200F
Croloy 5-Si	5% Cr 0.50% Mo 1.50% Si	1300F
Croloy 7	7% Cr 0.50% Mo	1250F
Croloy 9-M	9% Cr 1% Mo	1300F
Croloy 16-13-3	16% Cr 13% Ni 3% Mo	1600F
Croloy 18-8	18% Cr 8% Ni	1600F
Croloy 25-20	25% Cr 20% Ni	2100F

Write for your copy —on company letterhead, please

Chemical



Oil

Power

TA-1739 (P)

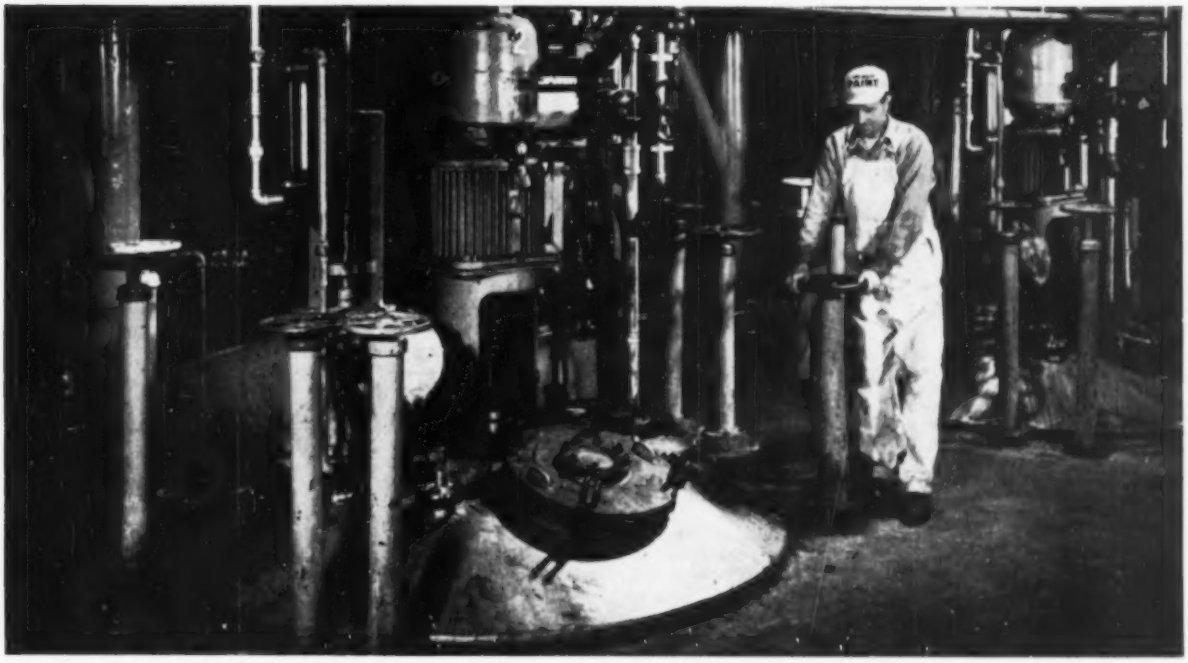
B&W STAINLESS and WELDED TUBES

THE BABCOCK & WILCOX COMPANY
TUBULAR PRODUCTS DIVISION
Beaver Falls, Pa.—Seamless Tubing; Welded Stainless Steel Tubing
Alliance, Ohio—Welded Carbon Steel Tubing

DOW

DOWTHERM . . . THE HEATING MEDIUM THAT ALSO COOLS

Developed by DOW, this modern heat transfer medium makes alternate heating and cooling possible in the same equipment!



Highly efficient Dowtherm®, used as a vapor for accurate high temperature process heating, may be utilized as a liquid when your processing cycle calls for alternate heating and cooling in the same equipment. This provides a versatile system in which a series of accurately controlled temperatures is possible without transferring the material being processed. Dowtherm, as a liquid coolant, is particularly valuable in reactions where it is necessary to absorb heat at high temperatures.

If your process calls only for heating, a Dowtherm vapor system will provide up to 750°F. heat, precision controlled by simple pressure regulation. Since Dowtherm does not contain any minerals, there are no costly scaling problems in your vaporizer or processing equipment . . . only a minimum of routine maintenance is required.

Dowtherm was created by the Dow research team for the chemical, petroleum, paint, food and other process industries—has helped to increase production and even made possible new products. To learn how you can gain these benefits write to THE DOW CHEMICAL COMPANY, Midland, Michigan, *Dept. DO 3-7A*.

you can depend on DOW CHEMICALS

DOW

Investigate the

ARTISAN

ENGINEERING AND MANUFACTURING APPROACH TO YOUR SPECIAL PROCESSING PROBLEMS

For prompt consideration and reasonable delivery of special chemical-mechanical equipment.

- ***Chemical Engineering* DESIGN.**
  A staff of qualified chemical engineers, accustomed to working cooperatively with the engineers and management of process manufacturing companies . . . specially trained men whose recognized achievements have resulted in their being retained as consultants on many process installations.
- ***Mechanical Engineering* DEVELOPMENT.**
  A complement of mechanical engineers who pool their specialized abilities in equipment design to develop in detail the mechanical units required to economically operate your specific chemical process.
- ***Facilities for* MANUFACTURING.**
  Integrated resources for fabrication, including modern shop equipment for heavy sheet metal forming, specialty welding, and all machinery operations.

Your call or letter will bring an Artisan engineer to give you more complete information.

ARTISAN METAL PRODUCTS INC.
73 Pond Street, Waltham (Boston 54), Massachusetts
PROCESSING EQUIPMENT *DESIGNED, DEVELOPED, MANUFACTURED*

YOUR FILTERING PROBLEM A SPECIAL ONE?

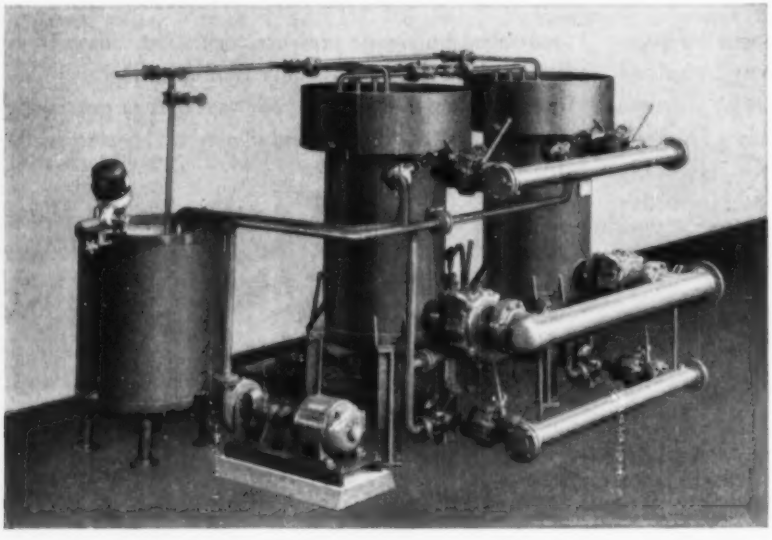
Then it's even more important that you find out what PORO-STONE filtration can do. Shown below is an Adams packaged plant for continuous filtration of molten phosphorus. Whether "special" or "standard" your filtering problem is met by experienced engineering and competent production at R. P. Adams.

ADAMS *PORO-STONE* FEATURES

- permanent filter media
- backwash without disassembly
- "packaged" ready for use
- with or without filter aid

Write for Bulletin No. 431

R. P. ADAMS CO., INC. 240 PARK DR. BUFFALO 17, N. Y.



NOTED AND QUOTED

That Human Problem Again!

In Uganda, people resisted the introduction of well-lighted and ventilated houses, which could be built with native materials almost as easily as the traditional low doored, windowless huts they were living in. Why did they object to a change? Because, they said, low doors and no windows keep out "the evil eye" —the spirit that causes all illness, poverty and death.

In an Indian village, farmers refused to change over to an iron plough. They felt it would be brutal to "mother-earth," that it would tear and break her body. "We shall use our old wooden ploughs" they said, "and our grateful land will repay with generous crops." Both of these stories show how changes must not be forced piece-meal, and must be accompanied by careful educational campaigns.

Sometimes there are short-range solutions possible. One study tells of a nutritional campaign in Thailand that had stalled because the people disliked cow's milk. The problem was overcome when someone introduced canned milk. The cans, you see, gave the people no mental picture of a cow. And soon they were quite happy drinking the white liquid that came out of tins.

UNESCO World Review

A Scholar's Responsibility

Academic responsibility means for the individual that he accepts fully, and without reservation, his obligations to the community of scholars of which he is a part. His first obligation is that of complete honesty in his work. While no man is entirely free from bias and prejudice, the scholar's goal must be that of impartiality and objectivity, both in his research and his teaching. He must be prepared to accept any conclusions which are dictated by his work and his own rational judgment thereon. If he has committed himself to membership in any totalitarian group which dictates beforehand the conclusions which he may draw from his work, he has no right to ask a society of scholars to keep him in their midst to protect him. He has disowned the basic principle upon which his society operates.

Grayson Kirk
199th Columbia Commencement

What's in a Name?

For example, one hears today much talk in the oil industry about a new field

Turn to page 12

Electrolytic Aids to

THE MODERN TEXTILE INDUSTRY

Chlorine and caustic soda, products of the electrolytic industry are essential in turning natural and man-made fibres into modern textiles of all kinds.

Uniformly high quality **GLC Graphite Anodes** are doing their share to help the electrolytic industry meet the ever increasing civilian and defense demands for chlorine and caustic soda.

ELECTRODE DIVISION

Great Lakes Carbon Corporation

Niagara Falls, N. Y. GLC Morganton, N. C.

Courtesy The Dow Chemical Company and The Saran Yarn Company

Graphite Anodes, Electrodes and Specialties

Sales office: Niagara Falls, N. Y. **Other offices:** New York N. Y., Chicago, Ill., Pittsburgh, Pa.

Sales Agents: J. B. Hayes, Birmingham, Ala., George O'Hara, Long Beach, Cal., Great Northern Carbon & Chemical Co. Ltd., Montreal, Canada.

Lawrence Vertical Top-Suction Liquid Oxygen Pump

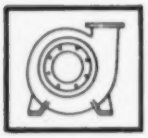
PUMPS to handle LIQUID OXYGEN

At —297.4° F. — the boiling point of liquid oxygen — many abnormal factors must be considered in designing a centrifugal pump. Metals become brittle . . . packing will freeze solid . . . the net positive suction head is usually very low, so that the liquid is at or near its boiling point. All of these difficulties are successfully overcome in Lawrence Vertical Top-Suction liquid oxygen pumps.

Lawrence construction employs metals not affected by the extreme low temperature and locates the packing far enough above the liquid so that it is exposed only to the oxygen vapors and functions normally. Location of the suction on top prevents vapor binding, even at boiling point.

If your problem involves pumping a liquefied gas at extreme low temperature, write us the pertinent details. No obligation.

Write for Bulletin 203-6 for summary of acid and chemical pump data.



LAWRENCE PUMPS INC.

371 MARKET STREET, LAWRENCE, MASS.

called petrochemistry. This may be a useful title but it is a singularly inaccurate and illiterate one, which must have been coined by some petrocephalic counterfeiter of names who didn't know, or didn't care, that the Greeks had a word for it.

James Bliss Austin

Which Scientist Do You Read?

Progress is not served when persons ignorant or careless of the scientific method try to determine what is scientific fact. The consequence of man's neglect of the scientific method in the fields of industry, commerce, agriculture, education, and health are in the annals of history for all to see.

Farrington Daniels
Head, Dept. of Chemistry
University of Wisconsin

It would be my thesis that those historians of science, and I might add philosophers as well, who emphasize that there is no such thing as the scientific method are doing a public service.

James B. Conant
Former President,
Harvard University

Disciplines and Disciplines

Toward the close of the recent war, in our atomic project we had a very heterogeneous group of scientists, engineers, Army and Navy men, and laborers. Though they were eager to do the job, it was not easy to get them working smoothly together. After a rather discouraging day, General Groves made this comment: "Compton, you know, you scientists don't have any discipline."

I asked him, "General, what do you mean?"

He said, "You don't know how to take orders and give orders."

I thought a minute before I replied, "General, I suppose that's right. We don't know how to take orders and give orders. But we do have a different kind of discipline. You see, there isn't anybody who can tell a research man what it is that he should be doing. He's got to figure that out for himself. But when he's figured it out for himself, he's got to make himself do it. The difference between a good scientist and a scientist that isn't so good is whether he will make himself do the thing that he sees needs to be done."

Arthur Holly Compton
The Nature of Creative Thinking

Turn to page 14

CONTROL PANEL
Hofman Liquid Oxygen Transport Unit

Note the accessibility of all instruments on this control board. At top center is the motor driven LO_2 Pump, for the transfer of liquid from the oxygen container. Can handle 100 to 150 gallons per minute against a head of 40 psig. Operates on a minimum of 15 psig suction head. Liquid level gauge is to the right.

VACUUM PUMP

This electrical motor driven vacuum pump permits evacuation of the insulation space. A removable filter prevents particles of insulation or other foreign matter from entering the pump mechanism.

Hofman Laboratories' new semi-trailer mounted Liquid Oxygen and Nitrogen Transport Unit is an important contribution to the nation's defense program as well as to thousands of industrial laboratories engaged in extreme low temperature work. In this 8 to 12 ton capacity mobile unit Hofman has met ever-increasing demands for the storage, transfer and transport of huge quantities of liquid oxygen while maintaining a minimum of evaporation loss under all conditions. The equipment is designed to withstand severe shock loads, even when operating in the roughest terrain.

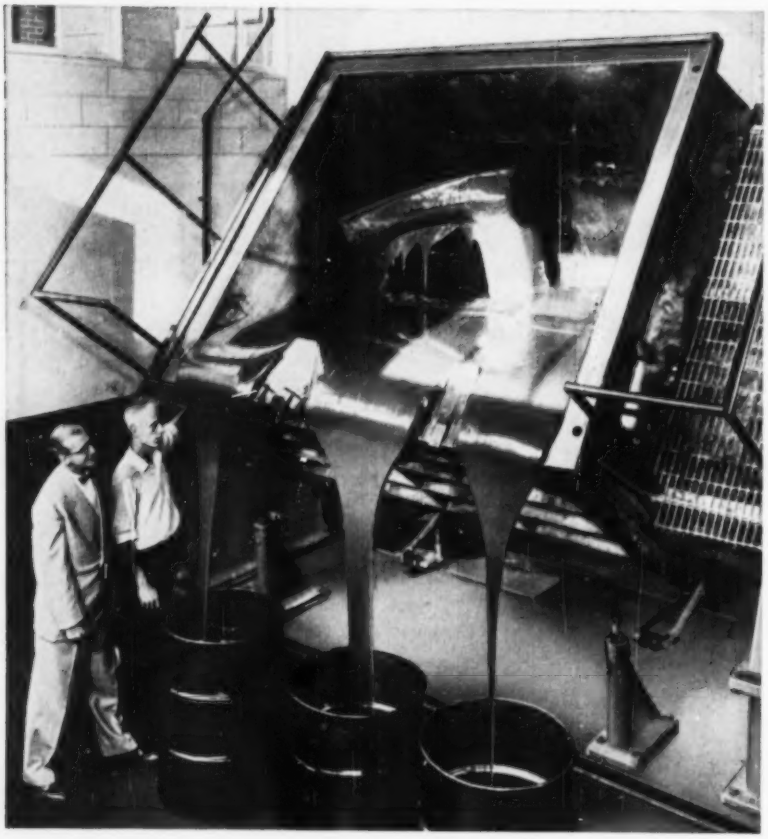
This is just another example of how Hofman Laboratories is keeping pace with the rapidly developing low temperature field, and that is why Hofman is your logical supplier whether your requirements call for 8-ton mobile liquid oxygen units or simply 5 litre containers.

Remember . . . Hofman equipment means high performance in the low temperature field. For information on Hofman low temperature apparatus, instruments and plants write:

hofman
LABORATORIES, INC.

Research Engineering, Design & Fabrication of Low Temperature Apparatus, Liquefication of Hydrogen, Nitrogen and Oxygen

219-221 Emmett Street, Newark 5, New Jersey



BAKER PERKINS builds world's largest color blending machine

Now in operation at the Hilton-Davis Chemical Company's plant in Cincinnati, this huge blender and flushing machine, designed and built by Baker Perkins Inc., mixes 1000 gallons of flushed colors at one time. That's roughly 15,000 to 30,000 lbs., depending on the specific gravity of the colors, nearly three times the capacity of any other blender in use today. The unit weighs 21 tons and took two years to design, construct and install.

You may not need the world's largest color blending machine, but you can't go wrong if you rely on the company that can build one. When you need good, dependable chemical mixing machinery that will help increase your production and keep your maintenance and operating costs low, it will pay you to consult a BAKER PERKINS sales engineer or write us today.

248-A

BAKER PERKINS INC.

CHEMICAL MACHINERY DIVISION • SAGINAW, MICHIGAN

A Place in the Sun

It is all too frequently the custom to regard the scientific outlook as in opposition to what is sometimes called the humanities. In England I certainly meet people of ability who are quite unashamed at knowing nothing of science—they even sometimes boast of it. I daresay there are some over here who do so too. But if anyone were to confess that he was bored by reading poetry or by listening to a symphony they would be really shocked. I want most strongly to protest against this way of looking at things. . . . The field of human knowledge is vast, and it would be fantastic to suppose that anyone could possibly be equally informed about all its fields, but every educated person ought to know a little about them all.

The most ardent musician does not expect the professional student of literature to have a deep understanding of the subtleties of counterpoint and harmony, but he does expect him to know a bit about music. I strongly make a similar demand for science. But at this point I ask whether we are going the right way about achieving this aim, and I rather doubt whether it is not the scientists who have failed. The books about science are usually written from a rather deeply technical point of view, with the aim, whether conscious or unconscious, of making the reader into a professional scientist, and that is not at all what is wanted. . . .

The writer has two dangers to avoid. One is the charge of merely giving a superficial smattering without transmitting the spirit, and the other is an even more insidious danger of our education. . . . It is the danger of the examiner and the examination. It is easy to test a student for facts, but very hard to test him about the spirit behind those facts, and there is a very serious danger that insistence on the student knowing something of science should kill his interest in the subject, in much the way that the Latinists have killed the interest in Latin literature for many of us by their insistence on an accurate knowledge of Latin grammar. That is the challenge. It has to be met if science, the queen of the arts, is to take its proper place in the world that has been created by the Scientific Revolution.

Sir Charles Galton Darwin

We grow old so fast, and smart so late.

Pennsylvania Dutch Proverb
Quoted by Arthur Linz

AMMONIUM NITRATE

Girdler designs and builds complete plants

GIRDLER has broad experience in handling complete plant projects . . . including design and construction of installations involving very high operating pressures, high temperature reactions, and corrosive substances.

Plants like this produce ammonia, ammonium nitrate, and nitric acid. Gases are handled safely and efficiently at pressures up to 15,000 pounds per square inch.

For ammonium nitrate or various other processing facilities, centralize design, engineering and construction responsibility with Girdler . . . and assure coordination and sound results. Call the nearest Girdler office for complete information.

GIRDLER DESIGNS processes and plants
GIRDLER BUILDS processing plants
GIRDLER MANUFACTURES processing apparatus

GAS PROCESSES DIVISION:

Chemical Processing Plants
Hydrogen Production Plants
Hydrogen Cyanide Plants
Synthesis Gas Plants
Plastics Materials Plants
Sulphur Plants
Acetylene Plants
Ammonium Nitrate Plants
Catalysts and Activated Carbon

the **GIRDLER** Company

A DIVISION OF NATIONAL CYLINDER GAS COMPANY

LOUISVILLE 1, KENTUCKY

GAS PROCESSES DIVISION: New York, Tulsa, San Francisco • *In Canada:* Girdler Corporation of Canada Limited, Toronto, Ontario

Fired at 1700°F., glassed steel gives you

the corrosion resistance of glass

plus **the working strength of steel**

In specially designed furnaces, at temperatures as high as 1700°F., the almost universal corrosion resistance of Pfaudler glass is combined with the working strength of steel. During this high heat period, *an interlocking chemical action takes place between glass and steel.* As the temperature is lowered, forces are set up within the glass itself which make it hard and tough. It has now become glass completely reinforced by steel.

Even at elevated temperatures and pressures, Pfaudler glassed steel is resistant to *all* acids except hydrofluoric. With a new Pfaudler glass, it is possible to handle not only acids but also *alkaline* solutions up to a pH of 12 and 212°F.

Pfaudler glassed steel reactors are built in capacities of 5 to 3500 gallons and for internal pressures as high as 200 p.s.i. These units have agitation, are usually jacketed, and are supplemented by a complete line of glassed steel accessories. Other types of glassed steel equipment include heat exchangers and condensers, distillation assemblies, and columns.

Write for Bulletin 894-F-2

PFAUDLER

THE PFAUDLER CO., ROCHESTER 3, N. Y.

FACTORIES AT: Rochester, New York; Elyria, Ohio, U.S.A. Leven, Fife, Scotland; Schwetzingen-Baden, Germany

Opinion and comment

ARE YOU GETTING YOUR NICKEL'S WORTH?

Are you getting your nickel's worth of public relations from the American Institute of Chemical Engineers? What do we mean? Why, that's all the cash money per member that Council has been able to budget annually for the activities of the Public Relations Committee, not counting special expenditures during the past six months for the recently completed National Survey Questionnaire.

What do you get for your money? Naturally, one thinks first of such obvious forms of publicity as releases to the daily newspapers and radio stations, covering local-section, national-meeting and annual-meeting functions and activities. Everyone who has attended these meetings must be familiar with the broad coverage given the Institute through announcements about the speakers and their subjects, interviews with officers and outstanding persons connected with the Institute. Even at affairs other than our own, such as the recent Petroleum Exhibition at Tulsa, Oklahoma, the Institute, through an interview with W. T. Nichols, was given prominent recognition in the press.

But publicity is only one of the concerns of the Public Relations Committee. Among other external activities are programs for improving lay knowledge of chemical engineering through the various subcommittees which have prepared among other things, the pamphlet "Know Your Institute" and the vocational guidance kits for use by groups interested in that subject at the local-section level. Others have prepared articles for publication in trade journals, nontechnical magazines, house organs, etc. Last February assistance and encouragement by a subcommittee resulted in notable participation by several sections in the nation-wide observance of Engineers' Week. One promising project currently undergoing study by a subcommittee is the proposed production of a documentary motion picture that will depict, in its true aspect, the nature and the achievements of chemical engineering as a distinct profession. In the same general theme, the proposed Speakers' Bureau, which is being organized in the South Texas Section (and it is hoped eventually in all the local sections), plans to make available to local civic, service, and other nontechnical organizations, speakers capable of addressing any meeting on the subject of chemical engineering, its part in the economy of the modern world, and its present and future objectives.

With an eye to the future, other projects are being formulated covering such things as the writing of the fifty-year history of the Institute, authorization of the issue of a commemorative stamp in 1958, development of plans and program for the half-century celebration, etc.

The activities of members of the Public Relations Committee even spill over the boundaries of the United States. There are two projects with international ramifications: one, a World-wide Survey of Chemical Engineering; the other, Pan American Chemical Engineering Activities. The unlimited potential in these two areas should provide a real challenge to the leaders of these activities and any who wish to work with them.

Along with the foregoing and other projects, we must single out with especial pride in 7,800 of our fellow members, the successful outcome of the recently completed National Survey Questionnaire. The preliminary tabulation was reported in the April issue of "C.E.P." The current issue contains the first correlations, and a later issue will summarize the special comments that were written in nearly 3,500 questionnaires. This analysis will be of immeasurable value to the Institute in achieving the least known of the three general objectives of the Public Relations Committee. This objective is "to improve the attitude of members of the Institute and Local Sections so that, instead of evaluating membership in the Institute in terms of how much they get from the Institute, they may look upon it as the organization through which they can contribute to the advancement of their profession." It highlights the continuing need for internal or member, relations as well as external, or public, relations.

Basically involved is the question of "pride of profession." The need for refreshing our professional attitude is manifested by the astonishing frequency of a certain type of comment found written in the questionnaires, which complained that the A.I.Ch.E., while doing a good job of providing technical and social background for individual improvement, still does little to improve the professional stature of engineering in the eyes of industry and the public. We are compared, in our relations with the public in general, to some of the other professions, and this professional stature is thought to be measurable in terms only by the relative monetary remuneration of members of the various professions. It is symptomatic of an unfortunate situation that such thinking should be taking place in minds of some of the membership. Every one in the Institute ought to dedicate himself to the improvement of the position of chemical engineering in our social and economic life through his own personal accomplishments, as well as through individual and group example of the ethics and purposes which guide this great profession. It is not the American Institute of Chemical Engineers as an organized group that alone should be responsible for the cultivation of the profession. It is equally the duty of every member to serve as its advocate, both on and off the job, for it is by the accretion of the efforts of individual upon individual toward continued advancement of the science and understanding of it, rather than by simple organization alone, that professional eminence is built. The Public Relations Committee earnestly recommends that each member of the Institute regularly and carefully devote a few moments to the editorials, news, and similar contributions by the officers, members of Council, Chairmen of Committees and other persons and groups, which will continue to appear in "C.E.P." The editor's policy of making space available for special messages should serve to reduce the number of persons who can say (as did some in the Questionnaire) that they are unfamiliar with procedures and practices of the Institute.

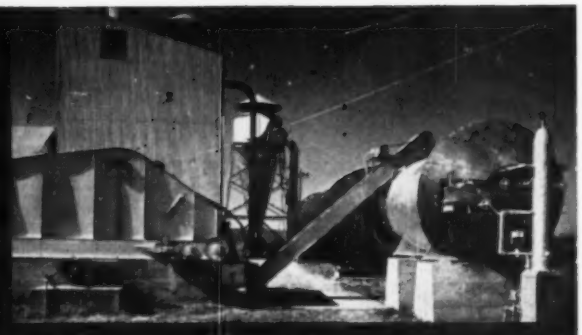
Do you, then, want more from the Public Relations Committee? If so, we must be mindful of President Nichols' recent statement "that a big part of the good done by the A.I.Ch.E. is the result of volunteer efforts by its members." Obviously, the annual appropriation of $500 for public relations cannot be expected to do much when compared with thousands of dollars some other organizations can spend for the employment of firms of public relations experts. It is our conviction that if enough members serve faithfully on the committees already in existence, giving freely of their time in a system that still gives full recognition to the value and need for free enterprise, the attainments will be surprising and gratifying.

If the Institute is to win public understanding, appreciation, and support it must make its fight on a precinct basis. What Community Chest or any campaign ever reached its goal if its efforts consisted solely of public appeals by the head of the campaign with no solicitations by individuals? What political campaign could succeed, no matter how good its issue or candidate, if there were no precinct organization to contact people directly and get out the vote? There have been altogether too few men, who have devoted themselves to this grass-roots espousal of the Institute and the chemical engineering profession.

The accomplishment in public relations most basic and most coveted of all is the reaffirmation by young America of the need for guarding and strengthening our system of free enterprise which has created and alone can perpetuate the productive and constructive arts and sciences, of which chemical engineering is an honored branch.

GEORGE F. JENKINS

more than 50 years of experience in designing and building dryers for industry...



Louisville dryers

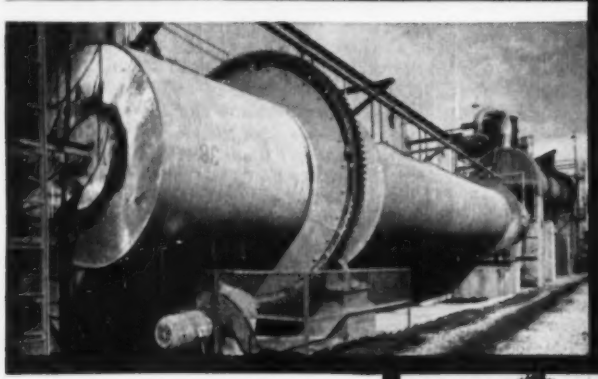
used throughout the world for great efficiency with low maintenance

LOUISVILLE DRYING MACHINERY UNIT

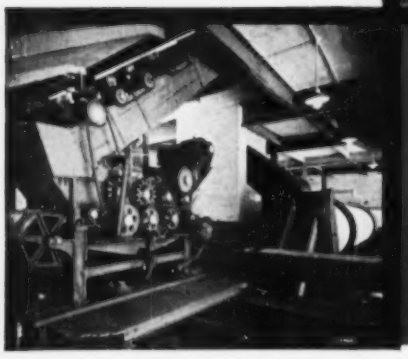
GENERAL AMERICAN TRANSPORTATION CORPORATION

Dryer Sales Office: 139 S. Fourth Street, Louisville 2, Kentucky
General Offices: 135 South LaSalle Street, Chicago 90, Illinois
In Canada: Canadian Locomotive Co., Ltd., Kingston, Ontario

OFFICES IN ALL PRINCIPAL CITIES



PROCESS EQUIPMENT DIVISION
GENERAL AMERICAN
TRADE MARK



KNOW THE RESULTS BEFORE YOU BUY

Louisville engineers will test your dryer needs in our laboratory. When required, a pilot model will be checked in your plant before full-size dryers are built.

Louisville's creative engineering pre-determines results for you!

The Manufacture and Distribution of Carbon Dioxide

H. A. Sommers

Food Machinery and Chemical Corporation, New York

Carbon dioxide—in solidified form known as dry ice—the wonder refrigerant of some thirty years ago, while not fulfilling the many claims then made for it, has nevertheless grown at a steady and accelerating rate until today it may be classed as a heavy chemical with a production capacity, liquid and solid, of more than 3,000 tons a day.

This paper contains (1) a survey of all the carbon dioxide plants in the United States with location, capacity, source of CO_2, absorbing solution and approximate cost of production, (2) a discussion of the factors affecting the possible value of sources of raw CO_2, (3) a brief resumé on the production of dry ice, and (4) a description of the present transportation methods for liquid and solid CO_2.

To give an idea of the size of the CO_2 industry it may be pointed out that the 1950 rate of production was one-third that of ammonia and one-fourth that of chlorine. The 1950 production expressed in per cent of the 1947 production will give a picture of how carbon dioxide is growing in comparison with other common gases, as shown in Table A:

Table A.

Gases	Per Cent
Hydrogen	215
Acetylene	180
Carbon Dioxide (liquid & gas)	170
Chlorine	145
Ammonia, Anhydrous	140
Oxygen	125
Carbon Dioxide (solid)	120

Figure 1 shows how liquid and solid CO_2 sales have grown since the year 1926 which might be considered as the beginning of the dry ice industry. Today there are fifty-seven liquid and solid CO_2 plants in the United States and there are few major cities in the country which do not have at least one plant. Table 1 gives a clear picture of how the CO_2 business is divided between the two major producers, Pure Carbonic and Liquid Carbonic and their associated suppliers, and Cardox Corp., Mathieson Chemical Corp., Wyandotte Chemical Corp. and a few others.

The recent consent decree signed in Federal Court, Brooklyn, ordering that an alleged monopoly in the manufacture and sale of carbon dioxide by five corporations be broken up may be of interest to a number of new companies having sources of by-product CO_2 which might be economically turned into a profitable product. In the case referred to, the complaint alleged the defendants monopolized and restrained manufacture and sale of carbon dioxide and dry ice and charged they joined forces and organized a joint patent-holding company (International Carbonic Eng. Co.) and so utilized their patents to prevent the manufacture of dry ice by others. It further charged the buying out of numerous competitors, purchasing the entire output of remaining competitors at fixed prices, engaging in price wars to drive competitors out of the field, and in other activities to restrain interstate commerce. Under the terms of the judgment, the corporations are required to license patents to any applicants on reasonable, nondiscriminatory royalty terms.

In the early days of the CO_2 industry there was considerable promotion based on the "making something out of nothing" idea—using "waste" CO_2 sources to make a valuable product. Mature reflection will likely show that a supply of raw CO_2 bears just about the same relation to the CO_2 business as a supply of air does to the oxygen business—there is potentially useful CO_2 in the products of combustion from any source, particularly those from coal, coke, oil or natural gas. Every process of fermentation reduces the sugar contained in the original substance to practically equal parts of alcohol and CO_2. The calcination of limestone gives off relatively high quality raw CO_2 and practically pure CO_2 is given off by many natural wells, sometimes under useful elevated pressures. Many chemical processes have as a by-product nearly 100% CO_2 gas, as for example, the removal of carbon dioxide in the manufacture of synthetic ammonia and the decomposition of soda ash in the manufacture of phosphates. There are many others.

Nevertheless, the sources just described, under some conditions and in some places, have value which they may possess by reason of four factors as:

Howard A. Sommers, chief engineer, Westvaco Chemical Division, Food Machinery and Chemical Corp., is a mechanical engineering graduate of Case Institute (1923). After several years of engineering work on liquid air plants, he joined Mathieson Chemical Corp., in 1925, serving successively as superintendent ammonia plant and assistant plant engineer at Niagara Falls, N. Y., superintendent dry ice and lime-recovery plants at Saltville, Va., project manager and plant manager of the Lake Charles, La., magnesium-chlorine plant during World War II and as chief engineer of the company, 1944-48. He then spent two years with Pure Carbonic as manager of carbon dioxide plant operations. He has recently been in charge of the engineering of the new Intermountain Chemical soda ash plant, now going into operation at Green River, Wyo.

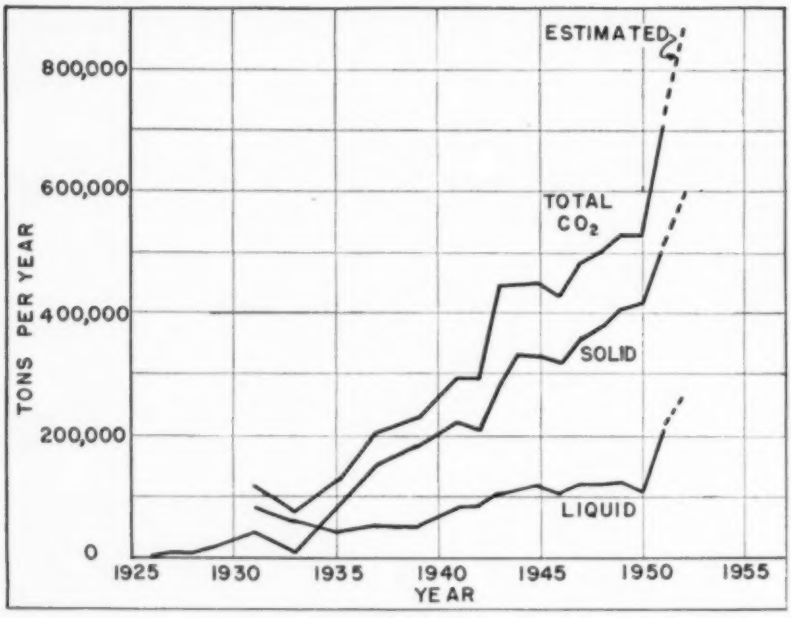


Fig. 1. Growth of CO_2 industry.

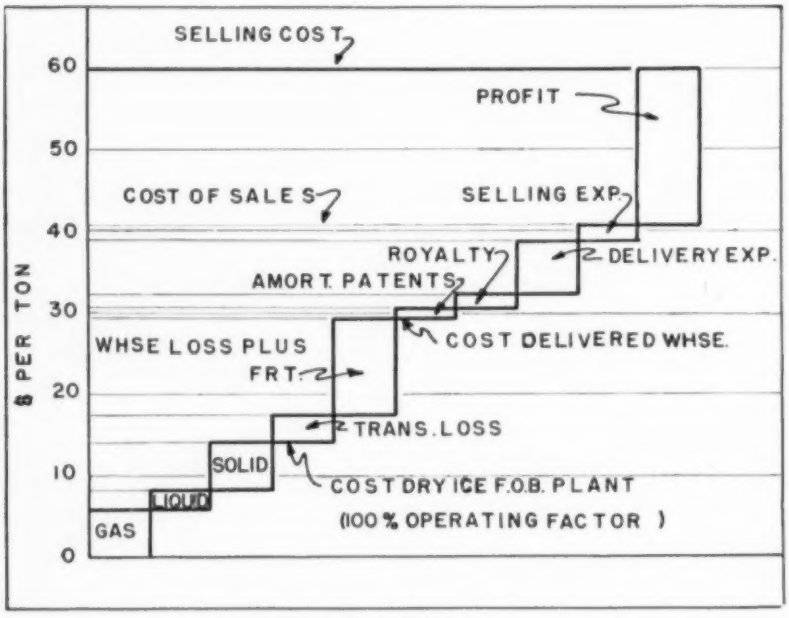


Fig. 2. Typical plant costs.

1. Safety factor
2. Location
3. Purity
4. Pressure

Safety Factor

This means the inherent nature of the CO_2 source which *guarantees* availability in the proper quantity and quality when needed. Any by-product source, as for example that from the CO_2 removal system in a synthetic ammonia plant, is subject to the ups and downs of the primary product and if the ratio of supply and demand of the carbon dioxide is high, even a minor dip in the market for ammonia will affect the dry ice plant. Further, operating troubles in one plant will almost immediately slow down or shut down the other and it will have to contend with this in addition to its own mechanical troubles. Most plants cannot afford the luxury of spare equipment, and minor troubles in either plant always result in lost production.

The cheapest ice ever produced is probably that from fermentation plants. The history of such plants, however, over the years is somewhat of a nightmare to the CO_2 industry—either there is a shortage of molasses, grain or other base material or there is a glut of alcohol. In any case, as frequently has happened, when the ice is needed most, the raw carbon dioxide is in short supply. The "self-contained" plant having as its only requirement a source of fuel, be it natural gas, coke or coal (usually with an alternate fuel), is gradually replacing most of the by-product plants.

Location

Manufacturing on a large economical scale away from the points of consumption from perhaps a preferred source of CO_2, or on a smaller, more costly scale at or near the consuming market is the dilemma facing the industry. Dry ice is peculiarly subject to large losses at all stages from the moment of manufacture and the cost of transportation and storage at the warehouse is quite high. The cost of evaporation plus freight is evident (*See* Figs. 2 and 5)—if the plant can sell directly from the presses, the profit possibilities are greatly enhanced.

These factors are, however, difficult to evaluate and it is probable that no clear case can be made for either arrangement. Mathieson's plant at Saltville, Va., in a remote location, is the largest in the world and successfully distributes dry ice over most of the Eastern part of the U. S., from New York City to New Orleans, La. On the other hand, Liquid Carbonic has found it economic to spread its capacity over some twenty-seven plants in all parts of the country.

Purity

The ideal purity is, of course, 100% CO_2 free of all solid and gaseous impurities. From 95-100% CO_2 can be compressed and liquefied directly, and purified (if necessary), preferably under pressure at relatively minor cost. Usually, if the gas is not close to 100% CO_2 it will have a CO_2 content ranging from about 12% (from a gas-fired boiler) to 25% from rotary lime kilns and up to 40% from vertical kilns. All these sources require absorption facilities and it is seen in Figures 2 and 5 that of the total cost of a ton of dry ice, about half goes to produce the 100% gas (lime kiln gas—monoethanolamine absorption).

Almost all sources of CO_2 gas have more or less impurity in them and while the removal of most any impurity is technically possible, it is safe to say that practically every plant is occasionally plagued with off-standard product through failure of the purification system. Minor impurities in the ice are difficult to detect at the plant and it

often seems that a minor odor and/or color is made worse as the ice ages.

Pressure

A few sources of 100% CO_2 have a definite value by virtue of their pressure. If the gas source requires little or no compression because of its originating at an elevated pressure, a small saving is possible. Compression from atmospheric pressure requires about 250 kw. hr./ton which amounts to $2.50/ton at $0.01/kw.hr. (lime kiln gas-purchased power). In a "self-contained" plant burning fuel under a boiler, it is possible to obtain the raw CO_2 and simultaneously generate steam to run the CO_2 compressors. The compression cost might be assumed to be more or less free depending on one's accounting procedure.

The plant of the Carbonic Chemical Co. at Mosquero, N. M., is an example of a practically ideal CO_2 gas source. Here the gas comes from six wells about 16½ miles distant and arrives at the plant at a pressure of 425-500 lb./sq.in.g. The supply appears inexhaustible. It runs 99.83% CO_2, the balance nitrogen —no other impurities except water vapor. However, the location is remote and adequate water is a problem. By the time this company's production reaches the Eastern markets, the cost has gone up several fold. Figures 2 and 5 are typical of a shipping situation of this kind. The diagrams are illustrative of a large plant using by-product gas from lime kilns and shipping to a typical warehouse 300-400 miles distant.

There are many natural CO_2 wells in California, New Mexico, Arizona, Wyoming and elsewhere, which were discovered in drilling for oil. Few are without contamination with hydrocar-

Table 1a.—Pure Carbonic Co. Plants

LOCATION	DATE BUILT	CAP.-TONS/DAY LIQUID	CAP.-TONS/DAY SOLID	PRIMARY AND ALT. SOURCE CO_2	ABSORBING AGENT	APPROX. PROD. COST/TON	SILO TONS CAP.
Alabaster, Ala.	1937	17	17	Lime Kilns	Potash	$20.00	0
Berkeley, Calif.	1935	60	55	Nat. Gas-Oil	M.E.A.	20.00	0
Charlotte, N. C.	1919	7 (cyls.)		Coke	Potash		0
Chicago, Ill.	1947	200	175	Coke Br.-Oil	M.E.A.	22.00	6,700
Deepwater, N. J.	1928	100	90	Fermentation	—	14.00	0
Jacksonville, Fla.	1932	10 (cyls.)		Coke	Potash		0
Kansas City, Mo.	1950	75	70	Nat. Gas-Oil	M.E.A.	16.00	0
Memphis, Tenn.	1932	11 (cyls.)		Coke	Potash		0
Niagara Falls, N. Y.	1929	100	90	CO Gas-Oil	M.E.A.	17.00	0
	Total	580	497				
U. S. INDUSTRIAL ALCOHOL CO.							
Anaheim, Calif.		15	15	Fermentation	—		0
Curtis Bay, Md.		30	30	Fermentation	—		0
New Orleans, La.	1937	40	38	Fermentation	—		0
OTHER ASSOCIATED PLANTS							
Calif. Carbonic Co., Los Angeles, Calif.	1939	20	18	Nat. Gas-Oil	M.E.A.	25.00	0
Carbonic Chem. Co., Mosquero, N. M.	1937		45	Wells	—	18.00	0
Commercial Solvents, Peoria, Ill.	1927	70	65	Fermentation	—	14.00	4,000
Publicker Com. Alc. Co., Philadelphia, Pa.	1930	175	150	Fermentation	—	14.00	0
Union Oil, Santa Maria, Calif.	1949	70	60	Ref. Nat. Gas	M.E.A.	12.00	0
Wyandotte Chem., Wyandotte, Mich.	1931	250	240	Lime Kilns	Potash	15.00	0
	Total	670	661				

Table 1b.—Cardox Corporation Plants *

LOCATION	DATE BUILT	CAP.-TONS/DAY LIQUID	CAP.-TONS/DAY SOLID	PRIMARY AND ALT. SOURCE CO_2	ABSORBING AGENT
Cabin Creek, W. Va.	1947	30	0	Coal	M.E.A.
Monee, Ill.	1946	35	25	Coke Breeze	M.E.A.
Niland, Calif.	1943	40	40	Wells	—
St. Louis, Mo.	1940	25	0	Coke Breeze	M.E.A.
Walden, Colo.	1945	30	0	Wells	—
	Total	160	65		
MISCELLANEOUS PLANTS *					
Carbon Dioxide & Chemical Co. — Price, Utah		5	5	Wells	—
Carbonic Products Co. — Tulsa, Okla.		10	10	Natural Gas	
Hiram Walker — Peoria, Ill.		60	50	Fermentation	—
Mathieson Chemical Corp. — Saltville, Va.		270	250	Lime Recovery	M.E.A.
New England Alcohol Co. — Everett, Mass.		20	20	Fermentation	—
Oklahoma Portland Cement — Ada, Okla.		10	10	Lime Kilns	Potash
Witt Ice and Gas Co. — Albuquerque, N. M.		10	10		
Spencer Chemical Co. — Military, Kan.		70	60	By-Prod. Ammonia Manuf.	M.E.A.
Henry Bower Chemical Mfg. Co. — Philadelphia, Pa.		4 (GAS)	—	City Gas-Oil	M.E.A.
	Total	459	415		
LIQUID CARBONIC CO. PLANTS †					
27 Plants in the United States	Total	1,300	1,200	Mostly Natural Gas and Oil	All Newer Plants M.E.A.

* Silo capacity zero. † No silos.

Table 1c.—Sales Distribution of Carbon Dioxide in the U. S.—1952

	PLANT CAPACITY—TONS/DAY			
	LIQUID	%	SOLID	%
Pure Carbonic and assoc. plts.	1,125	36	1,038	36
Cardox plants	160	4	65	2
Liquid Carbonic and assoc. plts.	1,425	45	1,320	47
All other plants	459	15	415	15
Totals	3,169	100	2,838	100

bon or other noxious gases, and the pressure may be variable and the supply over a long period questionable.

While no one source of carbon dioxide will usually be ideal from all four standpoints, the best combination will result in the cheapest product and greatest profit.

Manufacture of Carbon Dioxide

The manufacture of carbon dioxide has passed through a long development stage and has now reached a fairly well-defined art and most plants, while differing greatly in detail, accomplish the end products along quite similar lines.

Except for the by-product plants starting with 100% CO_2, the manufacture is divided into two main parts and in some plants, notably Mathieson and Wyandotte, the gas-producing and solid-producing plants are located at some distance from each other and run as more or less separate units. The self-contained plants, previously mentioned, operate as highly integrated units, the fuel being burned under boilers to produce raw CO_2 and steam, the high pressure steam driving the CO_2 compressors, pumps, etc. (and ammonia refrigerating compressors if a binary cycle is used), and the back pressure steam utilized to strip the absorbing solution.

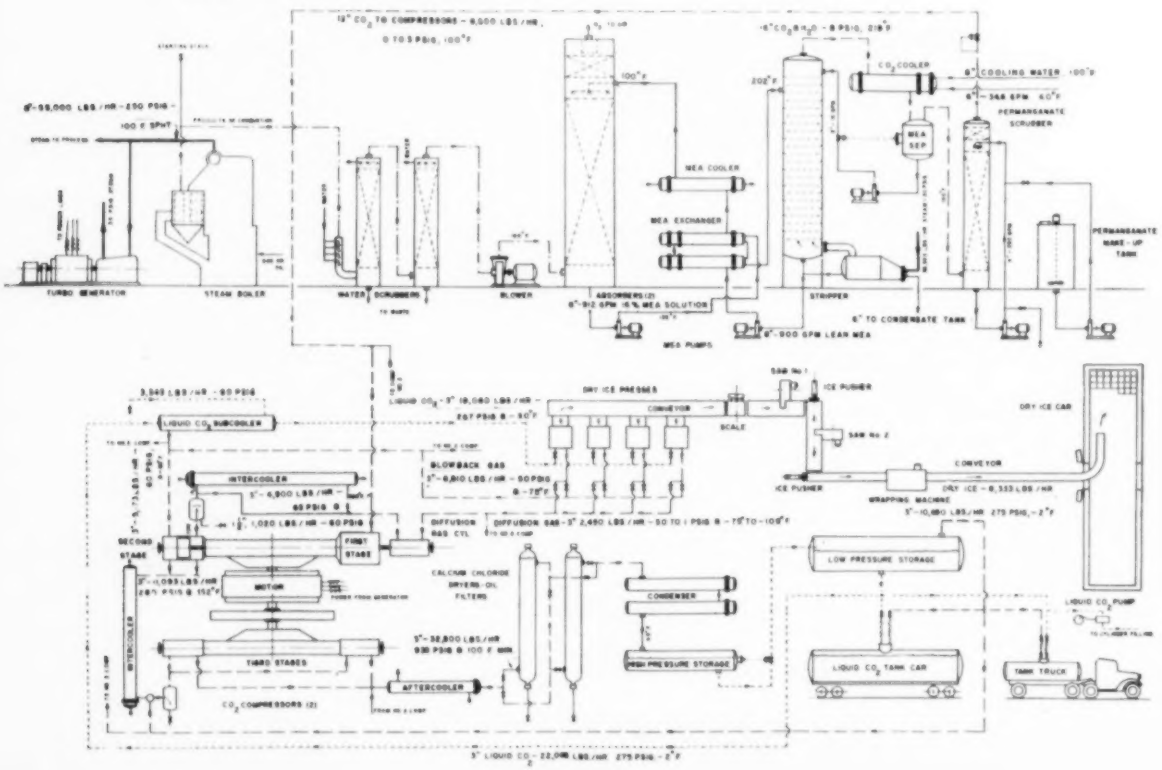
The majority of the plants now operating are of this type. Figure 3 shows a typical flow diagram. The fuel is preferably natural gas but oil, coke, coke breeze and coal are commonly used. Most plants have an alternate fuel as shown in Table 1. The choice of fuel is a matter of cost and operating difficulties will increase roughly in the order in which the fuels are listed.

The choice and arrangement of equipment are matters for careful chemical engineering, and the efficiency of the plant will be measured in the consumption, i.e., cost of fuel per ton of finished production. In addition to the basic cost of fuel, which is the primary but not final consideration, such factors as continuity of supply, continued low cost and the effect of the impurities in the raw gas on the absorbing solution must be considered. Natural gas can be controlled and burned under a boiler so as to result in nearly complete combustion with practically no impurities such as fly ash, sulfur dioxide or hydrogen sulfide, the oxides of nitrogen, and other gaseous impurities.

The absorbing solutions commonly used are saturated solutions of soda ash, potash, or monoethanolamine (M.E.A.). It will be seen from Table 1 that most of the newer plants now use monoethanolamine and it is probable that since the basic amine patents ran out several years ago, all future plants will use amine. In any plant which must burn a fuel to produce CO_2, the use of amine will permit a recovery in excess of 95% whereas soda ash or potash will operate in about the 50-65% range. Further, because of the high capacity of amine per gallon of circulation, the size of the scrubbers, absorbers, interchangers, coolers and pumps can be greatly reduced.

This is not the whole story, however,

Fig. 3. Flow diagram 100 tons/day dry ice plant.



as the high activity of the amine results in its picking up most of the impurities in the raw gas, and suffering chemical breakdown. The consumption of amine will run about 3-4 lb./ton of CO_2 in gas-burning units, 6-8 in coke-burning and 8-10 in coal-burning plants. The use of amine will make it necessary to use stainless steel tubes in the heating section of the stripper and in the exchangers whereas this would be quite unnecessary in soda or potash absorption plants.

Amine consumption is usually minimum when the oxygen in the raw gas is low and the strength of the solution likewise. Low absorber temperatures, the result of low cooling water temperature, also make for low amine consumption. Gaseous fuel, because it can be exactly controlled for maximum CO_2 and minimum oxygen (2% or less), as previously mentioned, is usually the ideal source of CO_2 even though the per cent CO_2 is quite low, around 12%.

It might be assumed that high CO_2 content, such as that from the burning of lime in the range 25-40% CO_2, would be decidedly preferable as a raw gas source. It is quite true that the higher CO_2 content means smaller equipment. However, horizontal and vertical kilns are inherently uneven in their operation because of ring formation, bridging, etc., and the effluent gas is likewise variable. This would not be too bad if the oxygen content was low but it is quite the opposite at times, and when the combustion swings the other way, i.e., there is insufficient air to burn the carbon in the fuel, the sulfur appears as H_2S (rather than SO_2 which is largely washed out in the water scrubbers) and the H_2S along with high CO has a deleterious effect on the absorbing solution.

In potash absorption plants, the solution picks up among other things, sulfates, chlorides, nitrites and nitrates which consume potash and must be circulated, heated and cooled and which affect capacity adversely. Of more importance, however, is the reducing effect of the H_2S (when occasionally present) as this causes the reboiler to prime and liberate large quantities of the oxides of nitrogen. It is disconcerting to have the dry ice turn up brown with nitric acid and the potash solution carried most of the way through the compression system. These problems have all been solved by one device or another. When it is considered that every CO_2 plant needs a minimum of 2½ lb. of back pressure steam/lb. CO_2 to liberate the gas from the solution be it potash or amine, and about 45 kw.hr. to produce a ton of gas plus 250 kw.hr. to turn it into dry ice, all of which is produced simultaneously in a self-contained plant, the worth of "free" lime kiln gas is questionable.

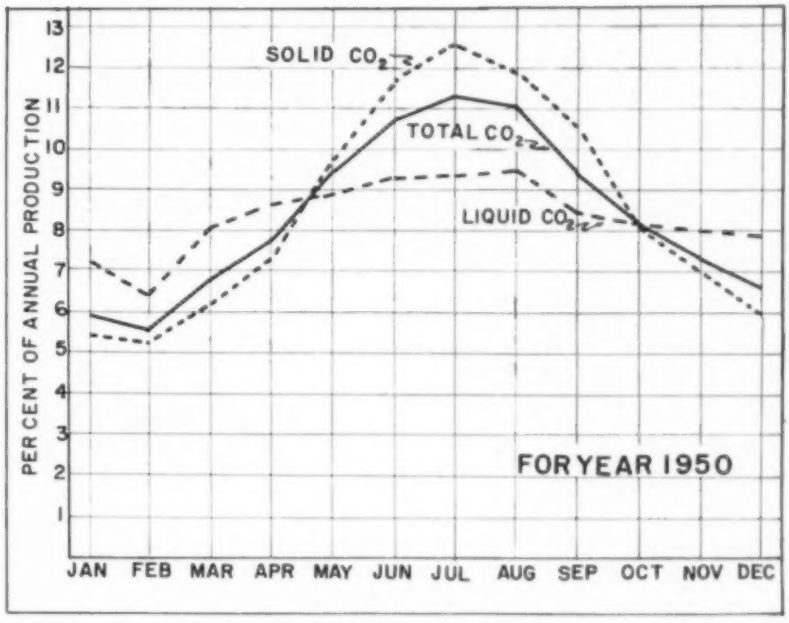


Fig. 4. Variation CO_2 production by months.

The answer is shown in Table 1 where the relatively small (70 tons/day) Kansas City plant can produce ice for about the same cost as the giant Saltville plant (250 tons/day) and do it at or near the point of consumption.

A version of a preferred cycle incorporating such features as will make for simplicity coupled with minimum power consumption and operating convenience is presented here.

Referring to Figure 3, the starting point is the boiler. Depending on the fuel, steam is generated at from 250 to 400 lb./sq.in.g., and if the plant is a large one (100 tons/day or more) the steam is expanded through a turbogenerator, the back pressure steam being consumed in the stripper. Power is generated and the CO_2-steam-power balance is such that the compressors, pumps, blowers, etc., are run without the need of any outside purchased power. The raw, hot flue gas is drawn through the water scrubbers by means of the blower where fly ash (if any), SO_2 and other impurities are mostly washed out and delivered to the absorption system. Here the flue gas is passed upwards countercurrent to the absorbing solution and most of the carbon dioxide is absorbed. The reaction is to form what might be called amine "bicarbonate" which when pumped to the reboiler and heated with back pressure steam reverses the reaction to "carbonate" liberating carbon dioxide and water vapor. The amine is cooled with water and is ready for another trip through the absorber. The carbon dioxide is cooled and passed directly to the first stage of a three-stage compressor.

A plentiful supply of clean, cold water is a decided help in producing low cost dry ice and, if at all possible, the plant location should be chosen with this in mind. If this is not possible, a binary cycle can be used with ammonia cooled condensers or preferably, cold water may be produced by the use of steam jet refrigeration.

The complexity and cost of a separate ammonia system are believed by some to be less desirable than steam jet refrigeration even though a condensing pressure of about 1,000 lb./sq.in.g. is required compared to 325 lb./sq.in.g. with ammonia.

Moisture removal can be effected before the first stage or after the first, second or third stages. The use of alumina or silica gel is common and the location after the second stage is considered preferable. Some prefer to use calcium chloride, if available at reasonable cost, and to locate the unit after the third stage (as shown) where oil vapor and water are removed simultaneously. It is possible to remove substantially all traces of oil and water in properly designed equipment which affects the physical quality of dry ice in an adverse manner.

The oil-water removal system is operated at about 100° F., in the gas phase, slightly above the critical temperature of 88° F.

Because of the slight vapor pressure of amine, it is mandatory to use a potassium permanganate scrubber to eliminate a sweetish odor in the dry ice and it may be located before the drier in any of the positions just described. It is not normally required when using soda or potash absorption unless the control of combustion at the raw gas

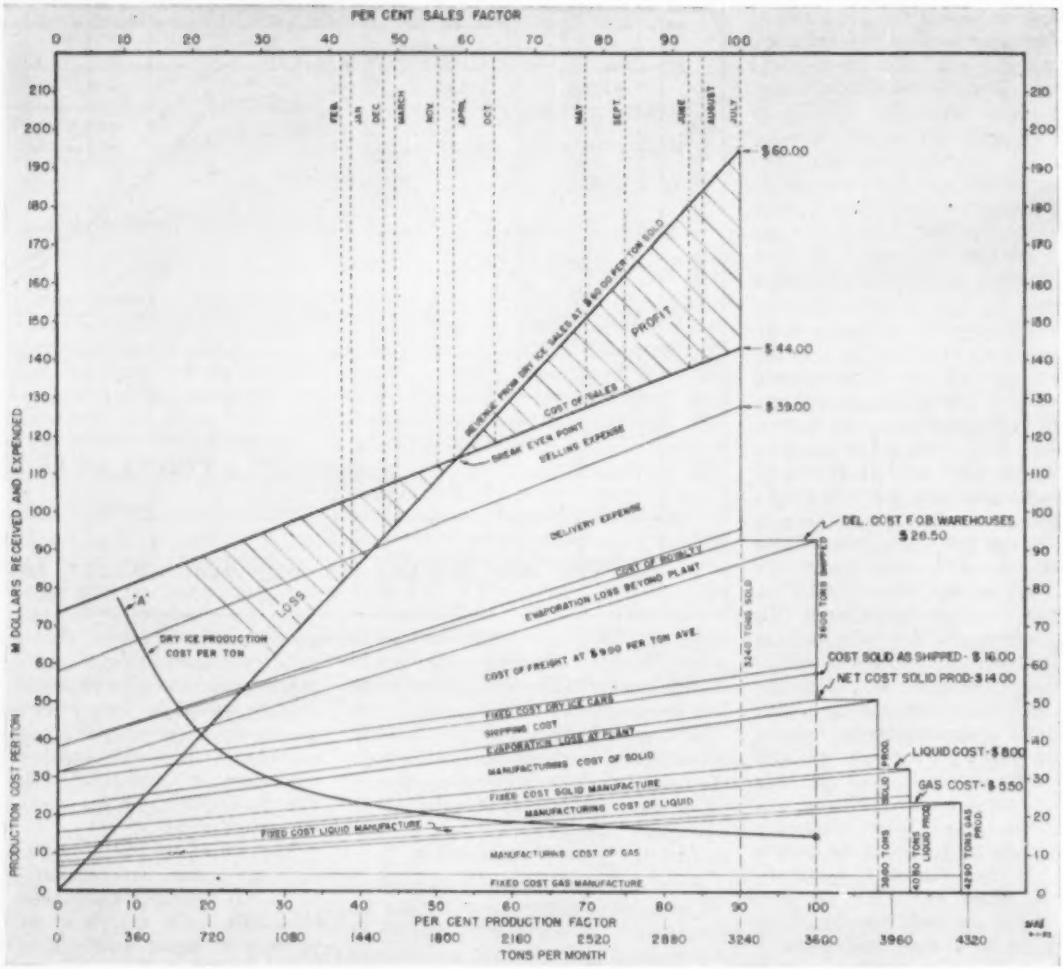


Fig. 5. Production-sales-income—costs.

source is poor and there is danger of decomposing the absorbing solution.

The heat of compression has been removed in the various intercoolers and aftercoolers, and condensation then takes place in the condenser. From this point on, the general idea is to drop the pressure in several steps, ending up with the coldest possible liquid carbon dioxide for admission to the dry ice presses. The liquid is flashed to about 275 lb./sq.in.g. and a temperature of —4° F. and then further cooled to —40° F. in a shell-and-tube exchanger. The blow-off gases are returned to the appropriate compressor stage and recompressed. About 4 lb. of liquid CO_2 at the condenser are required for each pound of dry ice produced.

Press operation consists of expanding the cold liquid into the chamber for about one minute at around 75 lb./sq.in.g. and then dropping the pressure to atmospheric. As the pressure passes through the "triple point" of CO_2, 60 lb./sq.in.g., "snow" is formed in the press chamber and when subjected to a hydraulic pressure of about 2,000 lb./sq.in.g. a block of dry ice results. Vertical presses producing 20 in. × 20 in. × 10 in. high blocks are universally used and after the bottom platen is lowered and the block ejected, they pass automatically on powered roll conveyors through two-band saws set at 90° with each other, cutting the blocks both ways, resulting in four 10-in. cubes. The cubes are then bagged by hand, automatically weighed and a belt conveyor delivers them to the cars or trucks.

The capacity of each dry ice press is 20-25 tons/day and the larger plants are equipped with automatic cycle controllers to take over the job of operating the many valves and press levers in proper and controlled sequence.

Automatic ice wrapping machines are now available but, to the writer's knowledge, the job is still being done by hand.

A completely modern and up-to-date plant, as above described, will cost $1,250,000 for a 70 ton/day plant or about $18,000/daily ton of capacity.

Most carbon dioxide plants produce and sell three products, liquid CO_2 in high pressure cylinders, low pressure (275 lb./sq.in.g.) low temperature liquid CO_2, and dry ice.

Dry ice acceptable to the trade must have the following specifications:

Complete freedom of odor and color.
A physical structure which will permit shipment, storage and sawing without breakage.
A density of about 90 lb./cu.ft.
A 10-in. cube with sharply defined edges.

As previously mentioned, properly designed and operated dry ice plants can eliminate substantially all of the moisture and oil from the product. This is highly desirable from a chemical standpoint but such ice would not withstand the rough handling in rail and truck shipment nor would it "age"—in a few days it would go "sugary" and be incapable of being sawed into thin slabs and be quite unacceptable to the ice cream industry. There is uncertainty among dry ice producers on how to produce ice with the best combination of properties but it is generally recognized that it is unwise to reduce the oil content below 50 p.p.m. If the carbon dioxide is dried excessively, as would be done in an uncontrolled alumina gel drier, say to —70° F., the resulting ice would not

age well. Experience has shown that the degree of drying one gets from calcium chloride, around −40° F., along with about 50 p.p.m. of oil, will give optimum quality in most cases.

Many additives other than oil and water have been tried from time to time to improve physical quality but their worth is questionable and, further, they impair the chemical quality. Proper amounts of water and oil coupled with correct press operation will produce ice which can be stored for as long as six months and still retain fair physical quality.

Like water ice, the demand for liquid and solid CO_2 falls off in the winter and most plants must adjust production accordingly. The monthly variation is shown (see Fig. 4) and the average yearly production output will be about 50-60% of capacity. The profit possibilities are seriously impaired as can be seen from Figure 5. Until new off-peak uses for dry ice can be developed, production will fall off in the winter. However, new winter uses for dry ice are constantly being developed and the ratio of winter to summer production is slowly rising.

An attempt has been made by Commercial Solvents and Pure Carbonic to solve the problem of high peak summer demand through the use of large storage silos holding 4,000 to 6,700 tons. Ice is loaded in the off season usually between February and May and unloaded as needed during the peak months, May through September. Losses average 20 to 25%. The cost of a silo will run around $250,000 or about the same as the capital cost of equivalent additional productive capacity. The labor of loading and unloading a silo is a costly and distasteful job and the resulting ice leaves much to be desired from a quality standpoint in a competitive market. A silo does possess the one important advantage of a supply of ice free of summer production troubles. On the other hand, "live" plant capacity is available as spare capacity during the winter months.

Transportation of Carbon Dioxide

The history of the development and production of most chemicals is closely allied to and parallel with the development of shipping containers and cars. Normally, because consumption of a new product is low, shipments are made in small lots. As plants get larger, individual shipments grow until full carloads are handled, if not to individual consumers, to warehousing or distributing points. This is true for both liquid and solid CO_2.

Liquid CO_2 started out shipped in 20- and 50-lb. cylinders. Unlike chlorine and ammonia, where 50-, 100- and 150-lb. cylinders have been used by the thousands, liquid CO_2 never got past the 50-lb. size. Chlorine shipments grew to ton containers, either singly or fifteen to a multiunit car, and then to 15-ton, 30-ton and finally to 55-ton single unit cars. The shipment of liquid CO_2 took an understandable detour when dry ice became available, through the use of liquefiers which convert ice back to liquid at the point of use. In this way the shipment of about 2 lb. of steel cylinder to and from the customer's plant was eliminated and a saving made as the ice cost at destination is only about ⅓ that of equivalent cylinder liquid.

As bottling and other large consumers grew in size, this method was superseded by the shipment of low pressure-low temperature liquid CO_2 (275 lb./sq.in.g., minus 4° F.) in insulated tank trucks holding up to 10 tons. At the plant, such liquid costs only about 60% that of dry ice and the expense of producing the latter, with all its incidental losses, was eliminated.

The next step was to ship in insulated 25-ton tank cars, similar to chlorine and ammonia cars, a procedure originally developed by Cardox.

During the last war, the problem of shipping liquid CO_2 overseas was solved by developing 150- and 300-lb./hr., skid-mounted, compact, self-contained production units which could make CO_2 as needed, for carbonation of soft drinks, fire extinguishers, etc. A semiportable plant of this type has recently been installed at the plant of Henry Bower Chemical Manufacturing Co., Philadelphia, Pa., at a cost of less than $50,000 and can produce CO_2 gas from city gas or oil at the rate of 300 lb./hr. for less than $30/ton. The cost of low pressure liquid CO_2 delivered by tank truck would be $65/ton. It is obvious that where one has a continuous and steady need for CO_2, this method should be preferred. Such a plant requires little supervision and makes the user completely independent of the normal supplier, winter or summer.

In the beginning of the dry ice industry, because of the small size of most plants and the low consumption at any one distribution point, it was common practice to ship in 45-cube containers, having about 6 in. of cork or other insulation and holding about a ton of ice. These containers were used for storage at the plant, as shipping containers, and for storage at the consuming point. Losses up to 50% were common and transportation costs high because of the high tare weight relative to the quantity shipped, high *LCL* truck rates and the cost of dead heading the empties back to the plant. Specially insulated bodies were built on trucks and dry ice routes developed, some of them a thousand miles or more long, but were not economical because of high operating costs.

The next step was to ship carloads (minimum carload 45,000 lb. except for the six winter months when it is 30,000 lb.) in ordinary refrigerator cars at commodity rates with or without supplementary insulation. Small plants took several days to load a car during which time the ice would be more or less exposed to the atmosphere. When such a car was shipped to low-consuming areas it might be en route and on sale for upwards of a month or more and under these conditions up to half of the ice loaded into the cars would be lost and much of the remaining blocks would be rounded cubes.

Special cars were then developed with 8-16 in. of insulation with up to eight separate compartments, loaded through the top; they were essentially the same as a number of insulated boxes inside a refrigerator car. Many arrangements were devised, some with walk-in cross aisles between compartments for easy access, some with outside doors and no cross aisles, all holding to the fundamental and technically correct top-opening principle. For small consuming areas these cars have proved to be the most efficient but, when plants grew to large size, it was found that although less efficient, a walk-in-type car was faster and more convenient to load and unload. Such cars are usually built starting with a standard water ice refrigerator and adding about a foot of insulation on floor, ceiling, sides and ends. The inside is lined with galvanized iron and every effort is made to keep the insulation dry. Such cars handle from 34 to 45 tons of ice depending on size and under normal conditions about 80-90% of the ice loaded is ultimately sold. There are about 700 special dry ice cars in service today in the United States.

Bibliography

1. Bureau of the Census, Inorganic Chemicals (1939-1946, 1950).
2. Goosman, J. C., *Ice and Refrig.* (December, 1929; August-December, 1930; January-July, 1931; February-December, 1936; February-April, 1937; June, 1937; October-November, 1937).
3. Hunt, F. B., *Refrig. Eng.*, **35**, No. 2, p. 83, (February, p. 83, March, p. 172, 1938).
4. Jones, C. L., *Ice and Refrig.*, p. 177 (August, 1931).
5. Jones, C. L., *Refrig. Eng.*, p. 17 (January, 1932).
6. Quinn, E. L., and C. L. Jones, "Carbon Dioxide," Rheinhold Publishing Co., N .Y. (1936).
7. Reid, George, *Refiner and Natural Gasoline Mfr.*, p. 72 (September, 1931).
8. Stickney, A. B., *Refrig. Eng.*, p. 334 (December, 1932).

PULSE COLUMNS

Richard Stephenson Oak Ridge National Laboratory, Oak Ridge, Tennessee

EDITOR'S NOTE

Last month Chemical Engineering Progress presented a paper by R. M. Cohen and G. H. Beyer titled "Performance of a Pulse Extraction Column." At that time we were mostly concerned with results. At the recent Toronto meeting, Mr. Stephenson of the Oak Ridge National Laboratory, gave a paper which dealt more with the construction and physical aspects of the pulse columns and as a quick adjunct to the Cohen and Beyer paper, we present here the "How to Make" article.

Perforated-plate or sieve-plate columns have been used for many years in solvent extraction operations. A pulse column consists of a sieve-plate column with the plate holes so small that no flow of liquid will occur unless one of the phases is pulsed. Columns are made of glass or stainless steel, built up by slipping plates and spacers alternately located along the axis of the column.

One of the two liquid phases present is pulsed at the rate of about 60 pulses/min., each pulse causing the liquid in the column to oscillate over a distance of about 0.5 to 0.9 in. Product overflows from the top of the column and aqueous product is discharged at the bottom of the column through a jackleg which maintains the interface at a constant level.

The main advantage of a pulse column is the small H.T.U. as compared to packed or spray columns. Satisfactory pulse column operation has been obtained for a density difference as small as 0.05.

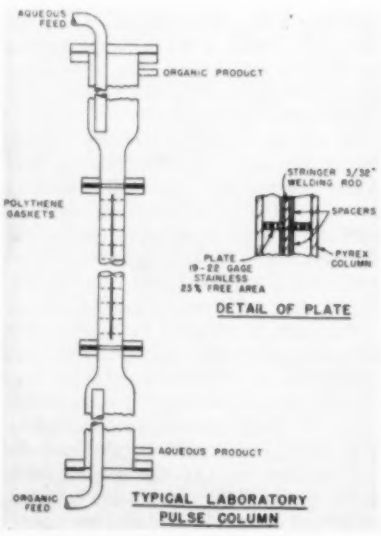
If the plates of a pulse column fit so snugly that leakage is prevented, a small scale-up factor will be involved in comparing columns of different size. Channeling will be almost negligible in a pulse column if the plates are level. In addition to varying the flow rates, it is possible to vary the pulse frequency, pulse shape, pulse displacement, hole size, free area and plate spacing. The chief disadvantages of pulse columns are small throughputs, a greater tendency to emulsify and the cost and operating difficulties of the pulser.

A Typical Laboratory Pulse Column

Figure 1 illustrates the Ellison laboratory pulse column (2) which is used at Oak Ridge. This column is made of 3-ft. sections of ½-in. Pyrex tubing, and since tubing of the proper tolerance is not available, the column sections are made from standard tubing by inserting a ½-in. stainless steel mandrel into the tube, maintaining a vacuum within the tube and heating to 600° C. in an oven for 8 hr. The glass shrinks to mandrel size. The cost of a 3-ft. section is about $5.00.

The column is built up of the required number of sections by bolting them together with stainless steel flanges and polythene gaskets. At the top and bottom of the column, 1-in. diam. separating sections about 6 in. long are welded on by bell-reducers. The feed lined are ¼-in. stainless tubing and are carried through the expanded section of the column to prevent possible mixing with the liquids leaving the column. Feed rates are controlled qualitatively by rotameters and are measured quantitatively by timing the flow rate from a graduated sight glass. The flooding rate is about 700 gal./(hr.)(sq.ft.) of the organic phase. Stainless steel tanks are used to hold the feed and product, and stainless steel or Tygon tubing for the feed lines.

The central stringer is 3/32-in. stainless steel welding rod sanded smooth. The circular plates are made from 19- or 22-gauge stainless, and contain thirty-two 0.039-in. holes arranged at the corners of equilateral triangles and corresponding to a free area of 21 to 23%. Spacers are made of stainless steel welding rod slightly larger than the stringer and drilled to fit over the stringer. Normally, thirty-four plates are used for a 3-ft. section. The cost is about $1/plate, including the cost of stringer and spacer. The pulse pump is a stainless-steel-bellows type having a ¾-in. bellows 3 in. long and a variable stroke. Its cost is about $125.



Operational Features

In addition to the bellows pulser, positive displacement pumps with all valves removed have also been used (3) for pulsing laboratory columns. Variable-speed drives are used to control the pulse frequency. In connecting the column to the pulser, operating difficulties may occur if the line is too long or too small. Thus, when the pulser reverses to withdraw liquid down the column, the velocity of the liquid in all the lines suddenly reverses and the pressure at the pulser becomes negative with respect to the pressure at the bottom of the column. If the pressure drop through this line connecting column and pulser is too high, the absolute pressure at the pulser may be less than the vapor pressure of the material being pulsed, and vaporization or cavitation may occur. This will prevent satisfactory operation of the pulser.

Two experimental studies of the performance of pulse columns were made at Oak Ridge by Griffith, Jasny and Tupper, who studied the extraction of nickel and copper, using water and methyl isobutyl ketone as solvents. The aqueous phase was maintained continuous in their experiments (3). The H.T.U. of the extraction column varied from 1.1 in. for low flow rates to a maximum of 34 in. at high flow rates, but in every case was below the value measured for a spray tower. The flooding velocity of the pulse column was smaller, however, namely, 955 gal./(hr.)(sq.ft.) compared with a value of 1,820 for the spray tower. The plate spacing was 1 in. and in all cases the volumetric ratios of the dispersed to the continuous flow rates were 1.57.

Belaga and Bigelow (1) studied the system water, acetic acid and methyl isobutyl ketone with the organic phase continuous. All experiments were made at constant flow rates and the H.T.U. varied from 2.63 to 6.25, depending on pulse height and frequency. These values are lower than those reported by other investigators for this system; values as low as 6 in. were reported for a ½-in. packed column and 7.5 in. for a wetted-wall extraction column.

Acknowledgment

The author acknowledges the assistance of C. V. Ellison, A. C. Jealous and W. E. Unger.

Literature Cited

1. Belaga, M. W., and J. E. Bigelow, U. S. Atomic Energy Commission, Declassified Document KT-133 (1952).
2. Ellison, C. V., personal communication.
3. Griffith, W. L., G. R. Jasny, and H. T. Tupper. U. S. Atomic Energy Commission, Declassified Document AECD-3440 (1952).

MIXED-BED ION EXCHANGE

A Symposium Covering Theory, Design of Production Units, and Production Results

Joseph Thompson, Francis X. McGarvey, John F. Wantz, S. F. Alling, M. E. Gilwood, and David R. Babb

Part I

Five of the papers presented in this symposium at the Chicago Meeting of A.I.Ch.E. are here amalgamated to provide a succinct discussion of current theory and data on mixed-bed ion exchange with some consideration of the principal applications.

Theory *

Monobed,† or mixed-bed, deionization involves the simple passage of a solution through an intimate mixture of a cation- and an anion-exchange resin. It achieves simultaneous and essentially complete removal of all ionized solids by a single passage through one bed of the combined exchangers. Prior to this development, deionization as commonly practiced involved the use of one or more sets of separate cation- and anion-exchange resin beds operating in series, and water qualities greater than 500,000 ohms specific resistance (1 part per million total ionized solids) were obtained only with a large number of such alternating units.

A mixed-bed deionizing unit is usually a pressure-type vessel fitted with three distributors. One distributor is located at the top of the unit, one at the bottom, and one midway between the two. A typical arrangement is shown in Figure 1. At the completion of an exhaustion cycle, the unit is backwashed at a controlled rate of flow to effect separation of the cation- and anion-exchange resin mixture. In a well-designed unit, with resins of carefully controlled properties, the anion resin rises to the top of the unit and the cation resin drops to the bottom as a result of this operation. Thereafter, alkali is introduced to, and rinsed out of, the anion-resin bed, generally by passage into the top of the unit and withdrawal of the waste regenerant through the intermediate distributor. In a somewhat similar manner, acid is passed into, and rinsed through and out of, the cation-resin bed, by use of the center and bottom distribution systems. When the major portion of the regenerants is washed from the resin, the water is drained from the unit to a point about 2 in. above the top of the bed. Air is introduced to promote thorough mixing, and the unit is returned to service.

Mixtures of weak-base anion-exchange resins and strong-acid cation-exchange resins, the first to be investigated in single-unit deionization, proved to be of little practical value. While it was possible with such combinations to obtain water of moderately high quality, the rate of deionization was fairly slow, and the wetted densities of the cation- and anion-resin components were too nearly alike to allow their separation for regeneration and reuse. Such resin mixtures were therefore adaptable only to one-use applications. They could not be used for commercial-scale deionization as applied to the treatment of water, sugar solutions, or other applications where economy of operation depends fundamentally upon reuse of the exchangers.

In 1948 strongly basic anion exchangers were introduced, making it possible to remove weak acids, such as carbonic and silicic, in addition to strong acids. Furthermore, these strongly basic resins, when mixed with certain strongly acidic cation exchangers of proper density, offered a number of advantages in the single-step deionization of various solutions such as raw-water supplies. These resins made possible the practical application of the mixed-bed method of deionization. Two of the major advantages of this technique are very high effluent quality, irrespective of influent characteristics, and more uniform performance of units in intermittent service.

CHEMICAL BASIS

Since all ion-exchange processes are equilibrium phenomena, an exactly quantitative removal cannot be effected by passage of a solution of an electrolyte through a column containing only a cation- or only an anion exchange resin. Depending upon the conditions of operation, leakage of some ions will occur, and it is generally considered to be a function of influent concentration, contact time, and dissociation constant of the resin-exchange groups. If a solution containing 1,000 p.p.m. electrolytes is passed through separate cation- and anion-exchange resin columns operated in series so that 10% leakage of ions occurs, the effluent solution will contain ions in a concentration of 100 p.p.m. If this effluent is in turn passed through a second identical set of columns, under the same operating conditions, 10% leakage will again occur and the treated solution will contain 10 p.p.m. ions. Leakage of ionic solids, therefore, can be minimized in a deionization system by the use of a number of alternating beds of cation and anion resin operating in series. In the mixed-bed system the concentration of ions in the solution is decreased in stages analogous to the theoretical plates of the theory of distillation, and the final product is of much higher quality (insofar as freedom from ionic solids is concerned) than the very best obtainable from multiple-bed systems operating under most favorable conditions. For example, when a cation- and an anion-exchange resin are mixed thoroughly in a 1-to-1 ratio, it can be assumed that the bed consists of alternate particles of cation and anion resins. If each of these particles is visualized as an individual unit, then a mixed bed may be regarded as a multiple-bed deionization system consisting of countless numbers of cation- and anion-exchange columns arranged alternately in series. The effectiveness of such a system in removing ionized solids from solution has been demonstrated by the conversion, under carefully controlled conditions, of a raw-water supply to conductivity water possessing a specific resistance in the range of 20,000,000 to 30,000,000 ohms (*4* and *5*).

There are several methods by which ions may be removed from solution. In the conventional deionization technique, the solution is passed through a cation-exchange resin, generally of the strong-acid type, which converts salts to their corresponding acids. These acids are then removed by passing the effluent through an anion-exchange resin. De-

* From "Theory of Monobed Exchange," by Joseph Thompson and F. X. McGarvey.

† Since Monobed is a trade name owned by Rohm & Haas Company, we will use mixed bed throughout these articles to describe ion exchange in a bed of cation and anion materials. Another name frequently used is Monotank.

Joseph Thompson and Francis X. McGarvey are with Rohm & Haas Co., Philadelphia, Pa.; John F. Wantz is with Illinois Water Treatment Co., Rockford, Ill.; S. F. Alling with Hungerford and Terry, Inc., Clayton, N. J.; M. E. Gilwood with The Permutit Co., New York; and David R. Babb with Elgin Softener Corp., Elgin, Ill.

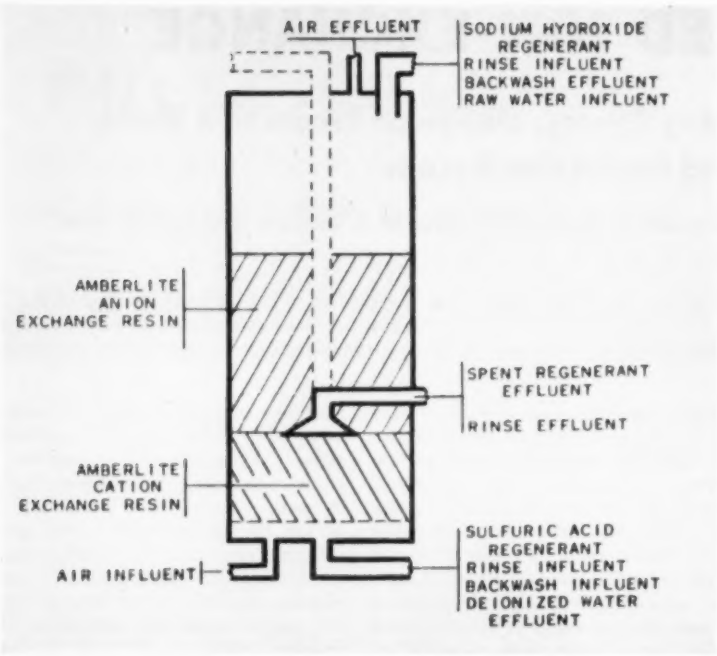


Fig. 1. Typical arrangement of a mixed-bed deionization unit.

pending on the characteristics of the solution to be treated and the desired quality of effluent, the anion resin may be of the strong- or weak-base type.

A reverse deionization technique may be advantageous under some conditions. In this method the anion resin must be a strong base to assure conversion of electrolytes into their corresponding hydroxides. The cation-exchange resin may be of the weak- or strong-acid type, operated in the hydrogen form. In mixed-bed deionization many combinations of cation- and anion-exchange resins can be employed to achieve simultaneous removal of anions and cations. For example, strong-acid-cation resin–strong-base-anion resin, strong-acid-cation resin–weak-base-anion resin, weak-acid-cation resin–strong-base-anion resin, and weak-acid-cation resin–weak-base-anion resin. But all are not equivalents, since the combination of strong-base-anion-exchange resin and strong-acid-cation-exchange resin has many more advantages than other combinations.

An examination of the equations involved is helpful in gaining an understanding of mixed-bed deionization. In a single column of strong-acid-cation-exchange resin the following reaction takes place:

$$R_z{-}H^+ + Na^+Cl^- \rightleftharpoons R_z{-}Na^+ + H^+Cl^-.$$

This reaction is reversible, and so, if any quantity of sodium resin exists in the lower portion of the column, leakage may develop and sodium chloride may appear in the effluent. In a single column of strong-base-anion-exchange resin, the following reaction occurs:

$$R_z{+}OH^- + Na^+Cl^- \rightleftharpoons R_z{+}Cl^- + Na^+OH^-.$$

This reaction is also reversible, and, since the chloride form of the resin may exist in the lower portion of the column, leakage may develop, as evidenced, again, by the appearance of sodium chloride in the effluent. When the resins are mixed together properly in a mixed-bed deionization unit, both these reactions take place. Moreover, because these reactions take place simultaneously in the presence of the hydrogen form of cation-exchange resin and the hydroxyl form of anion-exchange resin, neutralization also is experienced. This is demonstrated by the crossed equilibria operative in the system, as shown in Table 1 (*7*). It is apparent therefore that unfavorable exchange equilibria can be driven to completion in a mixed-bed unit. The key to the problem lies in the simultaneous removal of both cations and anions from solution, a feat that cannot be achieved with these same resins in separate beds. Thus, deionization may be accomplished even with a mixed bed of weak-acid-cation resin and weak-base-anion resin, although it must be kept in mind that the reaction rate is not so great as in a system of strong-base-anion resin and strong-acid-cation resin. The important fact is that normally unfavorable salt-splitting reactions may be driven essentially to completion by removal of one of the products of the salt-splitting equilibria from the scene of the reaction by a mechanism involving the more favorable neutralization equilibria.

The deionization equilibria involved in the operation of various types of mixed-bed systems may be summarized as shown in Table 2.

In a given mixed-bed operation each of the reactions may occur in the bed in any order or sequence. In addition to these effects, a further advantage is gained by the elimination of exchange zones after the components are mixed. In separate beds, exchange occurs in definite zones or bands in the bed, and concentration gradients are set up that promote leakage and undesirable regenerative effects. The air-mixing step in mixed-bed operation reduces concentration gradients and further minimizes leakage.

PHYSICAL CONSIDERATIONS

The physical characteristics of the individual exchangers determine whether the resins can be used in a practical mixed-bed application that permits separation and reuse of the resin. Particle size and true particle density are the factors involved in determining separability. Table 3 gives the true density and buoyancy of several exchangers commonly used in mixed-bed studies.

TABLE 1.—CROSSED EQUILIBRIA INVOLVED IN MIXED-BED DEIONIZATION

Type of reaction	Reactions: Cation exchanger	Reactions: Anion exchanger
Splitting of salts	$R_z{-}H^+ + Na^+Cl^- \rightleftharpoons \boxed{H^+Cl^-} + R_z{-}Na^+$	$R_z{+}OH^- + Na^+Cl^- \rightleftharpoons \boxed{Na^+OH^-} + R_z{+}Cl^-$
Neutralization	$R_z{-}H^+ + \boxed{Na^+OH^-} \rightleftharpoons R_z{-}Na^+ + H_2O$	$R_z{+}OH^- + \boxed{H^+Cl^-} \rightleftharpoons R_z{+}Cl^- + H_2O$

TABLE 2.—DEIONIZATION EQUILIBRIA OF VARIOUS MIXED-BED SYSTEMS

A. Strongly acidic cation exchanger—strongly basic anion exchanger

1. Reactions on cation exchanger:
   a. $R_zSO_3H + Na^+Cl^- \rightleftharpoons R_zSO_3^-Na^+ + H^+Cl^-$ (Salt-splitting)
   b. $R_zSO_3H + Na^+OH^- \rightleftharpoons R_zSO_3^-Na^+ + H_2O$ (Neutralization)

2. Reactions on anion exchanger:
   a. $R_z^+OH^- + Na^+Cl^- \rightleftharpoons R_z^+Cl^- + Na^+OH^-$ (Salt-splitting)
   b. $R_z^+OH^- + H^+Cl^- \rightleftharpoons R_z^+Cl^- + H_2O$ (Neutralization)

B. Strongly acidic cation exchanger—weakly basic anion exchanger

1. Reactions on cation exchanger:
   a. $R_zSO_3H + Na^+Cl^- \rightleftharpoons R_zSO_3^-Na^+ + H^+Cl^-$ (Salt-splitting)
   b. $R_zSO_3H + Na^+OH^- \rightleftharpoons R_zSO_3^-Na^+ + H_2O$ (Neutralization)

2. Reactions on anion exchanger:
   a. $R_zNH_2 + H_2O \rightleftharpoons R_zNH_3^+OH^-$; $R_zNH_3^+OH^- + Na^+Cl^- \rightleftharpoons R_zNH_3^+Cl^- + Na^+OH^-$ (Salt-splitting)
   b. $R_zNH_2 + H^+Cl^- \rightleftharpoons R_zNH_3^+Cl^-$ (Neutralization)
   c. $R_zNH_2 + H_2O \rightleftharpoons R_zNH_3^+OH^-$; $R_zNH_3^+OH^- + H^+Cl^- \rightleftharpoons R_zNH_3^+Cl^- + H_2O$ (Neutralization)

C. Weakly acidic cation exchanger—strongly basic anion exchanger

1. Reactions on cation exchanger:
   a. $R_zCO_2H + Na^+Cl^- \rightleftharpoons R_zCO_2^-Na^+ + H^+Cl^-$ (Salt-splitting)
   b. $R_zCO_2H + Na^+OH^- \rightleftharpoons R_zCO_2^-Na^+ + H_2O$ (Neutralization)

2. Reactions on anion exchanger:
   a. $R_z^+OH^- + Na^+Cl^- \rightleftharpoons R_z^+Cl^- + Na^+OH^-$ (Salt-splitting)
   b. $R_z^+OH^- + H^+Cl^- \rightleftharpoons R_z^+Cl^- + H_2O$ (Neutralization)

D. Weakly acidic cation exchanger—weakly basic anion exchanger

1. Reactions on cation exchanger:
   a. $R_zCO_2H + Na^+Cl^- \rightleftharpoons R_zCO_2^-Na^+ + H^+Cl^-$ (Salt-splitting)
   b. $R_zCO_2H + Na^+OH^- \rightleftharpoons R_zCO_2^-Na^+ + H_2O$ (Neutralization)

2. Reactions on anion exchanger:
   a. $R_zNH_2 + H_2O \rightleftharpoons R_zNH_3^+OH^-$; $R_zNH_3^+OH^- + Na^+Cl^- \rightleftharpoons R_zNH_3^+Cl^- + Na^+OH^-$ (Salt-splitting)
   b. $R_zNH_2 + H^+Cl^- \rightleftharpoons R_zNH_3^+Cl^-$ (Neutralization)
   c. $R_zNH_2 + H_2O \rightleftharpoons R_zNH_3^+OH^-$; $R_zNH_3^+OH^- + H^+Cl^- \rightleftharpoons R_zNH_3^+Cl^- + H_2O$ (Neutralization)

TABLE 3.—DENSITY OF ION-EXCHANGE RESINS

Resin	Type of exchanger	True density in water, lb./cu.ft.	Buoyancy, lb./cu.ft.
IR-120	Strong-acid cation	80.0	17.6
IRA-400	Strong-base anion	70.0	7.6
IRA-410	Strong-base anion	70.0	7.6
IR-45	Weak-base anion	72.0	9.6
IRC-50	Weak-acid cation	75.5	13.1

TABLE 4.—EFFECT OF RESIN FORM ON DENSITY VALUES OF ION-EXCHANGE RESINS

Resin	Form	True density, lb./cu.ft.	Buoyancy, lb./cu.ft.
IR-120	H	79.0	16.6
IR-120	Na	80.0	17.6
IR-120	Cu	83.6	21.2
IR-120	Pb	87.0	24.6
IR-45	Cl	70.0	7.6
IR-45	SO_4	72.0	9.6
IRA-400	Cl	70.0	7.6
IRA-400	PbO_2	75.0	12.6

Experience has shown that a difference of about 6 to 8 lb./cu.ft. is necessary between the buoyancy values if resin components of similar sizes are to be separated easily. Systems that do not separate well in water can be fractionated by sink-float methods using brine of intermediate density (*2*).

Particle-size distribution plays an important role in separability. Materials with the same buoyancy can be separated by particle-size adjustment. Unfortunately, large particle sizes affect the rate of exchange adversely, while small particle sizes give low fluidization flow and high pressure drops. In general, buoyancy difference is the most satisfactory criterion for the selection of mixed-bed exchange resins.

Resin form affects separability in some cases. Table 4 gives some density changes as a function of resin form.

It is evident from these data that resins that are readily separated in one form may not separate so well in another. Swelling and degree of hydration also influence separability. Resin * IRC-50 swells as much as 100% when converted from the acid to sodium form. Naturally, such volume changes greatly influence the design of mixed-bed units. In many cases, weight and volume changes compensate, and so true density changes are not great.

Mixing the components of a mixed bed depends on the physical condition of the bed. In the case of air mixing, the tube diameter must be sufficiently great to prevent bridging with air bubbles (2-in. diam. is minimum for good operation). In addition, the water level in the tube must be at least 2 in. above the bed so that sufficient water is available to promote turbulence in the bed.

Design of Production Units

EXCHANGE MATERIALS †

For many years leading water-treatment firms and technical laboratories had recognized the advantages of mixed-bed deionization, but until recently they did not have the tools with which to work. It was easy to mix cation- and anion-exchange materials of equal density and observe removal of ionizable solids from solutions, but it was not possible to separate them and use them for repeated operation. Since such a procedure would be too expensive for commercial application, all effort was turned toward finding materials of different density. Two exchangers of different density were found, but as they had to be separated in a sugar or brine solution, equipment was designed for pilot plant study.

* In this case, Amberlite, a trade name of Rohm & Haas.

† From "Design of Mixed-Bed Ion-Exchange Units," by J. F. Wantz.

A center vessel housed the two exchangers during operation. The tank containing brine was connected to the center vessel, and brine was pumped up through the exchanger separating the anion- from the cation-exchange material. Since the density of the anion material was less than that of the cation, the anion material floated out of the tank and into the anion regenerant tank on the left. The two exchangers were then regenerated separately. Once the regenerations were complete, the anion resin was drawn hydraulically back into the exchange vessel and remixed with the cation-exchange material.

While this system worked, complete separation was difficult, and its design was too complicated for commercial application.

When polystyrene anion-exchange material was introduced, its density proved sufficiently different from polystyrene cation-exchange material to allow complete separation. Even more important was the discovery that complete separation could be accomplished with water alone. Again a pilot plant was designed, and tests were started which led to the basic design of mixed-bed equipment and the ultimate installation of the first commercial model.

EQUIPMENT

The design of the exchange vessel for mixed-bed units is different from that of conventional two-bed units. As an aid to unit operators, an observation window should be installed so as to allow visual inspection at the top of the resin bed as well as at the interface of the cation and anion exchangers. A minimum freeboard of 100% of resin-bed depth should be allowed.

Distribution of water and chemicals is accomplished by an upper, lower, and middle header or radial lateral system. All three distributors should be fabricated of noncorrodible material. The upper distributor can be of normal design. The middle distributor, which is embedded in the exchange material, has to be designed to allow passage of water and regenerant chemicals without allowing passage of exchange materials. During backwash and exchange-material separation, severe pressure is exerted on the middle distribution system. It is normally fabricated of a noncorrodible metal and supported by internal tank bracing. The laterals of this distributor are screened to prevent loss of exchange material. Several types of screening, including stainless steel, Hastelloy, or Saran, can be used.

The lower distribution system can be one of several designs. If a flat bottom on the exchange vessel is used, the bottom distributor can be of the same design as the middle distributor. On small exchange vessels where flanged heads can be practically used, a distributor plate covered with a noncorrodible screen has proved satisfactory, but this design is limited to smaller tank sizes. Normally, 24-in.-diam. tanks are considered the dividing line. A fourth distributor can be used for the distribution of anion regenerant. This distributor is placed just above the top of the exchange-material bed.

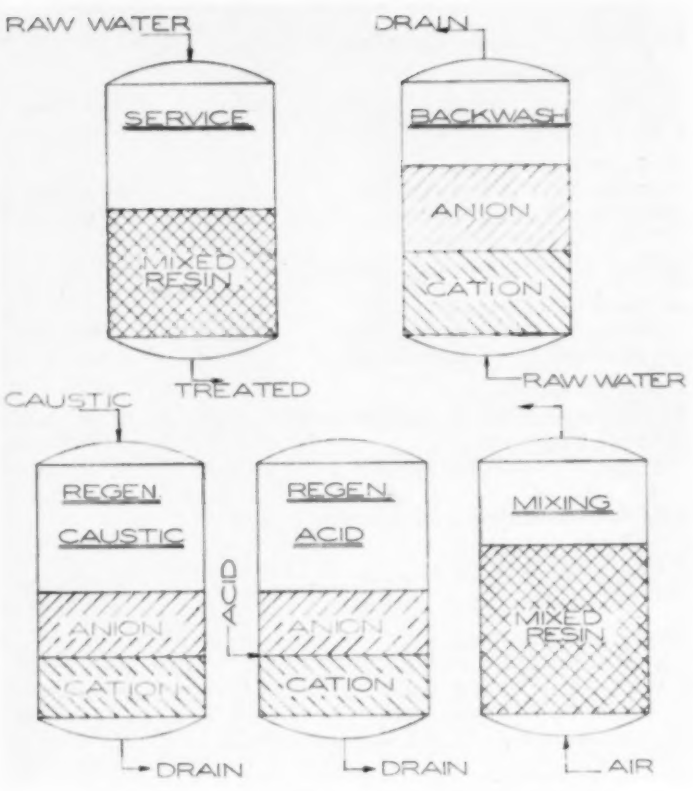


Fig. 2. Mixed-bed regeneration by alternate caustic-acid method.

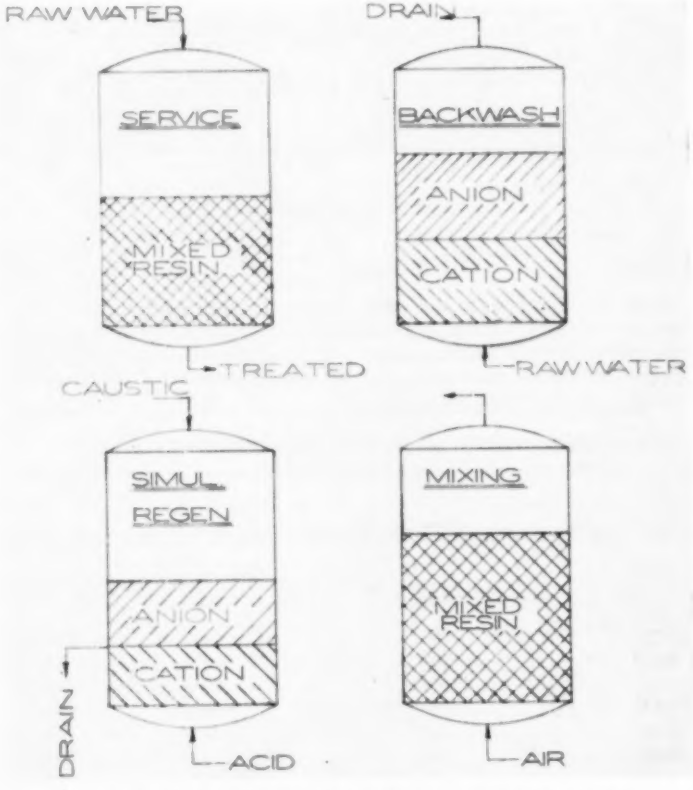


Fig. 3. Mixed-bed regeneration by simultaneous caustic-acid procedure.

OPERATION

Operation of the entire plant can be entirely automatic. Anion-exchange material is regenerated at a temperature of 95° F., which has been determined to be the most economical and efficient temperature level. On small equipment the necessary controls to regulate caustic-regenerant temperature sometimes are not justified from an equipment-cost standpoint. As a general rule, such temperature-control equipment is not considered on units having less than 20 cu. ft. of anion-exchange material.

Two-step Method. In the development of the mixed-bed unit, two basic operating systems were introduced. The first involved a two-step regenerating procedure, shown in Figure 2. First the backwash loosens the bed and separates the exchange materials; next caustic is passed downward through both the anion- and cation-exchange material; acid then passes downward from the middle distributor through the cation-exchange material; and finally air mixing takes place and the material is returned to operation.

The two-step system allows the greatest savings in component parts; however, it has several drawbacks. During the anion regeneration, caustic passes through both anion and cation exchangers. The magnesium ions which have been removed by the cation exchanger react with the hydroxide ion to form magnesium hydroxide. This requires high acid dosage to dissolve and carry to drain. If all magnesium hydroxide is not removed, it will tend to dissolve slowly during operation, causing impure treated water.

Equally as important is the fact that cation-exchange material is converted to the sodium cycle by contact with caustic. Sodium is one of the most difficult ions to remove from an untreated water supply, and in reverse is one of the hardest to remove from exchange material. Unless high acid dosages are used, all the sodium will not be removed. During operation the sodium will leach into the treated water, resulting in impure water. Using a softener as a pretreatment overcomes the magnesium hydroxide problem. However, double treatment is required and the problem arises of converting the cation-exchange material to the sodium form.

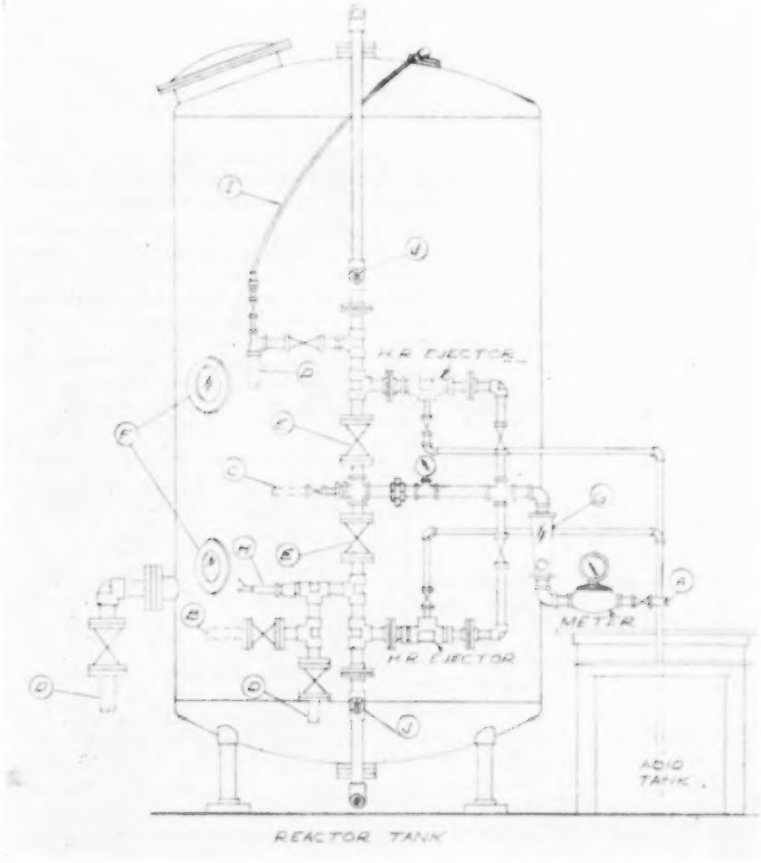


Fig. 4. Mixed-bed deionizer showing piping-control arrangement.

Simultaneous Method. Figure 3 shows the sequence of operation and regeneration of the simultaneous method. The first step is to backwash and separate the exchange material. Next the anion- and the cation-exchange materials are regenerated simultaneously. This is accomplished by passing the caustic downflow through the anion bed and acid upflow through the cation bed. Both regenerants are withdrawn simultaneously from the interface of the two exchange materials through a distribution system at that point. After the materials are rinsed, they are mixed by air and again are ready for operation. This method requires an elaborate regenerant system; however, it is more than justified by the water it produces. In addition, this method does not require presoftening, as does the two-step system. Both methods require soft water for anion regeneration when the magnesium content of the untreated supply is such as to cause magnesium hydroxide precipitation.

Figure 4 shows the valve and piping arrangement of a standard mixed-bed deionizing unit. This is a manually operated unit consisting of a manifold of diaphragm-operated valves; it is designed for simultaneous regeneration and has two regenerant systems, one for acid and one for caustic.

CONSTRUCTION MATERIALS

Normally, piping on units with pipe sizes of 2 in. and under is fabricated of plastic-base material such as Uscolite or Saran. Over 2 in., units are fabricated with steel pipe lined with either rubber, Saran, Neoprene, or Koroseal. Saunders-type diaphragm valves are used in this instance. These valves are fabricated of polyethylene or Saran or lined with rubber, Saran, or any of the many plastic coatings.

On the inlet there is, in addition to a standard water meter, a flowmeter to assist the operator in obtaining proper flow-rate settings during operation and regeneration. On the outlet there is a conductivity or pH controller that will sound an alarm or shut down the unit when the solids of the treated water exceed preset limits. Since a deionizing unit is not and should not be used as a filter, it is good practice to install prefiltration equipment to remove suspended solids from the raw-water supply. To ensure a clear effluent, a polish filter is normally placed on the outlet line.

SILICA CONTENT

When experiments showed that available methods for testing the purity of the effluent were insufficient, a cooperative program with two leading instrument manufacturers developed instruments capable of indicating and recording ac-

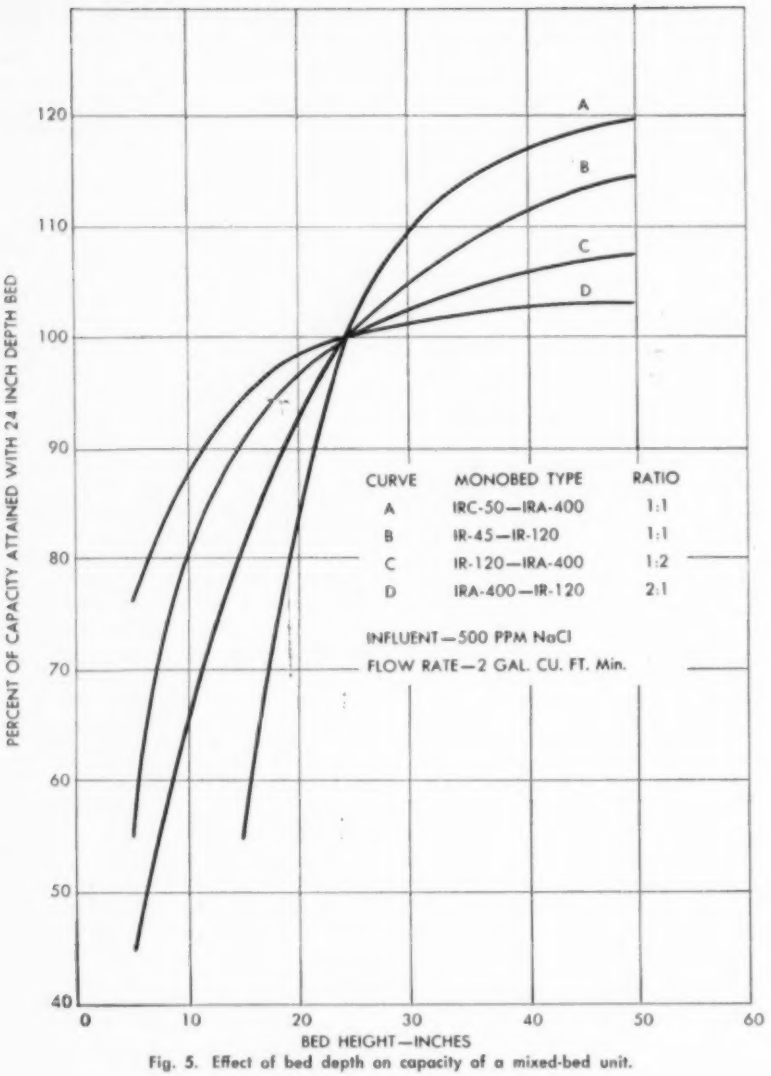


Fig. 5. Effect of bed depth on capacity of a mixed-bed unit.

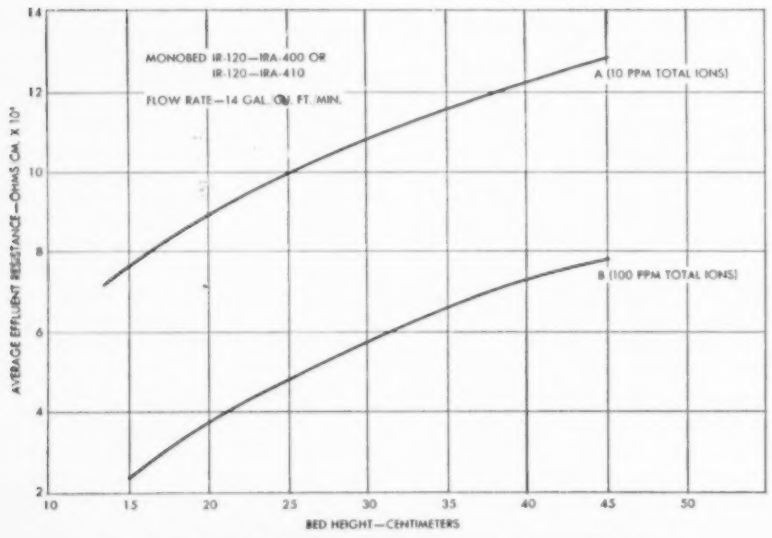

AVERAGE EFFLUENT RESISTANCE—OHMS CM. X 10⁴
BED HEIGHT—CENTIMETERS
MONOBED IR-120—IRA-400 OR
IR-120—IRA-410
FLOW RATE—14 GAL. CU. FT. MIN.
A (10 PPM TOTAL IONS)
B (100 PPM TOTAL IONS)

Fig. 6. Effect of bed depth on quality of effluent of a mixed-bed unit.

curately the solids content of an effluent having specific resistances up to 20,000,000 ohms/cm. Silica still remained an undeterminable factor, but a method for determining silica accurately in concentrations as low as 0.005 p.p.m. will soon be announced.

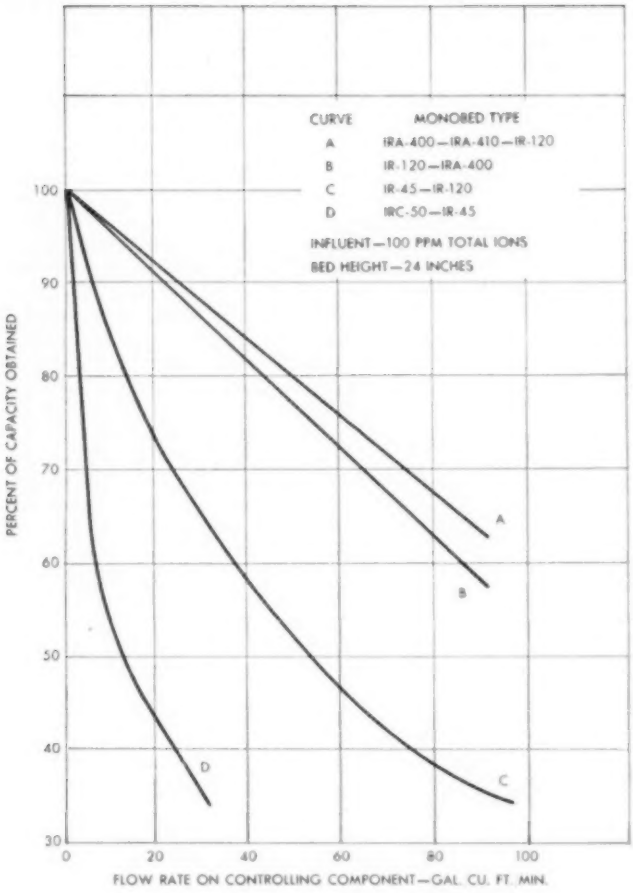
Since silica content in the effluent is of extreme importance to many applications, considerable research work has been done to determine a satisfactory automatic means of controlling the operation and shutdown of equipment at the point of silica break-through. Silica break-through actually takes place just prior to change of *p*H in the treated water. After installation and operation, the relation between silica break and *p*H change can be plotted with regard to total capacity. A continuous sampling tube is placed within the exchange-material bed at a predetermined level above the bottom of the bed so that the *p*H of water within the exchange vessel at that point will govern the operating cycle and eliminate silica break-through.

OPERATIONAL FACTORS *

Effect of Bed Depth. Bed depths above 24 in. have little effect on mixed-bed capacity. Below this value the capacity drops off markedly at normal flow rates. Figure 5 illustrates this variable. The bed depth also has an effect on quality, as may be seen in Figure 6, where average resistance is plotted as a function of bed depth at constant flow rate. Curve *A* shows the results for a 10 p.p.m. T.D.S. water, curve *B* for a 100 p.p.m. T.D.S. water. Since ion exchange is influenced by diffusion rates, it is not surprising that bed depth plays an important role in the exchange capacities of mixed-bed systems. Generally speaking, the relationship between capacity and bed depth is similar to that experienced in single-bed operation.

Rate of Reaction of Ion-Exchange Resins. Strong-base and -acid exchangers exhibit much greater exchange rates than do exchangers of the weakly acidic and weakly basic materials. The effectiveness of mixed-bed operation depends largely on the components in the bed. Figure 7 shows the effect of flow rate on capacity based on runs on 24-in.-deep beds. Flow rates have been calculated based on the controlling component of the resin mixture. This is the minor component by volume in the case of strong-base–strong-acid or weak-base–weak-acid exchanger combinations and is either the weak-base or -acid component when these resins are combined respectively with strong-acid or -base exchangers. These data show that mixed beds maintain a considerable degree of capacity even at flow rates far greater

* From Thompson and McGarvey.



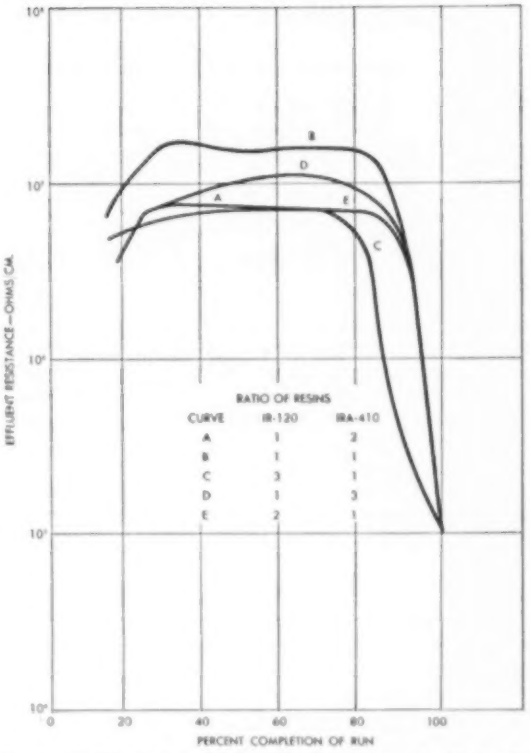


Fig. 7. Left, Effect of flow rate on the capacity of a mixed-bed unit.

Fig. 8. Above, Effect of resin ratio on effluent quality and capacity of a mixed-bed unit.

TABLE 5.—QUALITY OF MIXED-BED DEIONIZED WATER AS A FUNCTION OF CONTACT TIME IN RUBBER TUBES

Distance from unit, ft.	Specific resistance, ohm cm. × 10^6 2 gal./cu.ft./min. flow	5 gal./cu.ft./min.
0.5	12	14
1.5	8	12
3.0	6	9
10.0	3	6

than those usually employed industrially.

Reaction and flow rate also have a marked effect on quality of treated solution. Quality is poor at low flows because of pick-up of traces of contaminants from the equipment itself. After the flow rate reaches a certain value (8 to 12 gal./cu.ft./min. in this case), the quality remains independent of flow until a limiting flow is reached. Above this rate the column is no longer able effectively to remove electrolytes, and the quality drops rapidly.

Resin Ratio. As may be expected, the volume ratio of cation to anion resin has an effect on effluent quality and capacity. Under certain conditions it is desirable to vary the ratio of exchangers, depending on their capacity and the composition of the solution to be treated. Figure 8 illustrates variations in effluent composition when the resin ratio is changed. It is noted that the effect on quality is not great except for curve *C*, where the ratio of resin IR-120 to resin IRA-410 is 3 to 1. Since in this case the anion exchanger is used to remove weakly acidic carbon dioxide, as well as chlorides, the effect of higher anion to cation ratios (3 parts IRA-410/1 part IR-120) on water quality is more pronounced than in the case of inverse ratios of the resin components (1 part IRA-410 to 3 parts IR-120); i.e., the best ratio for good mixing and resin-particle distribution should be 1 to 1. This view is supported by curve *B*.

OTHER FACTORS

Trace Contaminants. As was suggested previously, residual solubility of materials of construction of the mixed-bed unit and trace quantities of leachables in the exchangers themselves will appreciably influence quality, particularly on initial operation. In solutions of very high quality, the effect of trace contaminants sloughed from the equipment may be extremely difficult to eliminate. Consequently, quality usually improves as flow rate increases. Table 5 shows how the specific resistance of a water is depreciated when it merely passes through gum rubber tubing.

Electrolyte pick-up by high-quality water is extremely rapid. A trace of carbon dioxide will reduce resistance by millions of ohms. Any residual solubility in equipment usually can be reduced by continuous leaching with high-quality water.

Large Ions. Occasionally certain waters, although crystal clear, may contain small amounts of large-molecular-weight organic substances or colloids from industrial or natural wastes. Such waters may give considerable difficulty if a very high-quality water is desired. Until the proper combination of resins was used, poor performance was encountered with a mixed-bed unit used to treat the water supply of a large eastern city. The data of Table 6 were obtained during an investigation of this difficulty.

The fact that a high-quality treated effluent was obtained with the local well water, but not with the city water, when the same mixed-bed test column was used, indicated that the city water con-

TABLE 6.—QUALITY OF EFFLUENT WATER FROM MIXED-BED UNIT

Run	Resins used in mixed bed	Source of water supply	Average resistance, ohm cm. × 10^6
A	IR-120–IRA-410	City water	0.5–0.6
B	IR-120–IRA-410	Distilled city water	4.0–6.0
C	IR-120–IRA-410	Local well water	5.0–7.0
D	IR-120–IRA-410	Recheck city water on Run C	0.4–0.5
E	IR-120–XE-98 †	City water	10.0–15.0

† A porous homolog of IRA-410.

tained a contaminant not readily removed by the normal deionizing technique. Deionization after distillation substantiated this conclusion. Finally, very high-quality water was obtained by the use of a porous anion-exchange resin as the anion component of the mixed-bed system. This pointed to the presence of a high-molecular-weight organic substance or a colloid as the source of the trouble.

Separability and Degree of Component Mixing. It is important that reasonably complete separation of exchangers be accomplished prior to regeneration; otherwise, ineffective regeneration and even fouling of the bed may result. Strongly basic anion exchangers exhausted with silica may become fouled with insoluble silica polymers if washed with strong acid or solutions of calcium and magnesium salts. Calcium sulfate, magnesium, and calcium carbonate and magnesium hydroxide may precipitate as a result of poor separation. Fouled resins will not separate well in mixed beds, and so, once the condition has started, the performance of the bed may be expected to become progressively worse. However, none of these objectionable conditions will be encountered if the resins are separated and regenerated properly.

Complete mixing is needed for the best quality effluent. Unmixed zones at the bottom of a column permit hydrolysis and subsequent leakage of ions. This is particularly important when weakly acidic or basic materials are being used.

FILTRATION *

For over 50 years it has been known that in the cleaning of a filter-sand bed with water and air, the applied air loosens the suspended matter that has attached itself to the sand grains during the filtering process, and the wash water then carries this loosened material out of the filter being backwashed or cleaned. In filtration work it is axiomatic that a clean filter will produce clean water.

Likewise it has been found that in the mixing of two resin beds with air in a mixed-bed unit, the air is very helpful not only in establishing the proper uniform mixing, but also in loosening particles of suspended matter which may have, though only lightly, attached themselves to the grains of resin. It is then easier for the wash water, after the completion of the operating run, to carry such particles of undesirable impurities out of the unit. This is very important because only perfectly clean resin can develop, over the years, full ion-exchange efficiency.

* From "Engineering Results with Mixed-Bed Exchangers," by S. F. Alling.

CONSTRUCTION INFLUENCES

The first mixed-bed units had internal parts fabricated, to a very large extent, of a brittle type of plastic. Generally speaking, this material was too hard and brittle, was subject to thermal change, and broke too easily during installation. Its use was to a great extent discontinued a year or so ago except in the case of a few special parts. Now the internal distributors are made of a thermoplastic type of material that machines easily and cleanly; has the necessary give, or resiliency; can with special equipment be bent or shaped; is unappreciably affected by normal temperature changes; and has been completely satisfactory in every respect. It is used for inlet, air, and regenerant distributors, for the underdrain or strainer systems, for bottom plates, and in many cases for the actual strainers.

As a precautionary measure these thermoplastic internal distributors, except those in the bottom supporting bed, are covered with an acid- and alkali-resistant polyethylene fabric, held firmly on the distributors with plastic wire. With this polyethylene fabric protecting all distributing orifices there is no chance of the resin grains or particles getting into and plugging these openings.

SUPPORTING MEDIUM

Many materials were studied for use as a supporting medium and distributor aid under the resin beds in the bottom of the mixed-bed unit. In the case of the conventional quartz-type gravel there was an undesirable pick-up of silica, while anthracite coal, which is nonsiliceous, was found to be too absorbent. Spun glass was tried, but it plugged too quickly and presented other difficulties. Moreover, it was desirable to keep all water inside the tank completely out of contact with metallic material of any kind.

After much research and experimentation, it was decided carefully to chip, or cut, acrylic acid stock material and then, with vibrating screens, to grade the particles into sizes approximating those used in the bottom of the conventional sodium-cycle zeolite-type water softener. This product is completely inert, nonsiliceous, nonmetallic, and nonabsorbent and, by actual tests at many installations, performs splendidly as a distributor aid for both the wash water and the mixing air from the bottom distributor system.

The air is applied to the bottom of the mixed-bed unit through an air-distribution system located beneath the supporting bed of graded plastic. If the water or air or both going up through this supporting bed should at any time for any reason upset the fine supporting layer at the top of the supporting bed, the unit would not be properly washed and cleaned, air and water would not continue to be uniformly distributed, regeneration would be relatively ineffective, and the capacity and efficiency of the unit would quickly drop. Consequently, it is necessary to hold the entire supporting bed in place and prevent its movement or disturbance at any time under any condition of operation. This securing is done with two rubber-covered wire-screen sections with a polyethylene fabric between, which are permanently connected to the mixed-bed container immediately at the top of the supporting bed. With this screen assembly in place, it is impossible for air and wash water to disturb or upset the supporting bed or for any appreciable quantity of resin to enter the supporting bed to affect its operating functions. As the water inside the mixed-bed unit never comes into contact with any siliceous or metallic material, silica or metal pick-up in the demineralizer is impossible.

Literature Cited

1. Bodamer, G., and Kunin, R., *Ind. Eng. Chem.*, **43**, 1082 (1951).
2. Daniel, F. K., U. S. Patents 2,461,505 and 2,461,506 (February, 1949).
3. Gilwood, M. E., *Power*, **91**, 86 (1947).
4. Kunin, R., and McGarvey, F. X., *Ind. Eng. Chem.*, **43**, 734 (1951).
5. Reents, A. C., and Kahler, F. H., *Ind. Eng. Chem.*, **43**, 730 (1951).
6. Robison, H. E., Pirsh, E. A., and Grimm, E. J., Am. Soc. Mech. Engrs., *Preprint*, 51-A-92 (December, 1951).
7. Rohm & Haas Co., *Tech. Bull.*, M-15-50 (revised November, 1951).
8. Straub, F. G., and Grobowski, H. A., *Trans. Am. Soc. Mech. Engrs.*, **67**, 309 (1945).

Part II will appear in a forthcoming issue.

Thermodynamics of Ammonia Synthesis and Oxidation

Roland H. Harrison and Kenneth A. Kobe

University of Texas, Austin, Texas

What new compound will join the many derivatives of ammonia? Thermodynamic calculations may be the first step in proving the feasibility of the chemical process. For such calculations the thermodynamic properties of ammonia should be known as exactly as possible. Also, the economic importance of ammonia dictates that its synthesis equilibrium be known exactly. Discrepancies exist in the present data, for a critical examination (*1*) of the heat capacity data shows that the curve representing the high temperature data does not merge smoothly with the curve representing the low temperature data. The high temperature curve has two inflection points which certainly do not represent the behavior of the ammonia molecule. Previous investigators, who calculated thermodynamic properties from spectroscopic data, did not consider all the effects which contribute to the molecular energy; also, some investigators used inaccurate frequency assignments. The present work gives accurate values of the thermodynamic properties of ammonia from 233.16 to 1500° K. and equilibrium constants for ammonia synthesis. The effects of process variables on the equilibrium yield of ammonia are shown.

R. H. Harrison is a Ph.D. candidate at the University of Texas, where he also received his B.S. and M.S. degrees in chemical engineering. He held the Dow Chemical Co. and Carbide and Carbon Chemicals Co. Fellowships while working on the master's degree. His doctoral research is also in the field of thermodynamics.

K. A. Kobe has been graduate professor of chemical engineering at the University of Texas since 1941 and associate director of the Bureau of Industrial Chemistry at Texas since 1946. He received a Ph.D. at the University of Minnesota in 1930. As chairman of A.I.Ch.E. Projects Committee he initiated the industry-sponsored schools for chemical engineering teachers and the annual listing of chemical engineering faculties. Professor Kobe set up a graduate school of petroleum refining engineering in Rio de Janeiro in 1951.

Previous Work

The most reliable data for the heat capacity of ammonia were determined at the National Bureau of Standards in 1925 by Osborne and co-workers (*27*), who used a continuous flow electric calorimeter to determine the heat capacity from −30° to 150° C. Heat capacity and other thermodynamic properties have been calculated from spectroscopic data on ammonia by Nernst and Wohl (*26*), Bryant (*2*), Kelley (*16*), Justi (*15*), and Thompson (*34*). These calculations used a rigid rotator, harmonic oscillator model for ammonia but the later calculations use more accurate frequency assignments. Haupt and Teller (*11*) made their calculated values agree with the experimental values (*27*) by including a term for centrifugal distortion and by assuming a rotation-vibration correction term which could not be used outside of the 0° to 150° C. range of experimental data. Spencer and Flanagan (*32*) used the data of Thompson and applied a correction for rotational distortion. Stephenson and McMahon (*33*) calculated accurate values for entropy and free energy by using a correction for centrifugal distortion and Kassel's rotational correction below 300° K. The best Third Law entropy value for ammonia gas at 298.16° K. has been selected by Kelley (*17*) as 45.96 ± 0.10 e.u., based on the work of Overstreet and Giauque (*28*).

Thermodynamic Functions

Thermodynamic functions for ammonia were calculated from the latest spectroscopic data using statistical methods (*24*). A correction was made for the anharmonicity of one of the vibrations of the ammonia molecule, a correction not considered by other workers above 150° C. The ammonia molecule may be considered as an example of the double potential minimum problem where the potential minima refer to the nitrogen-hydrogen vibrations with the nitrogen atom on either of the two sides of the plane formed by the three hydrogen atoms. It can be shown from quantum mechanics that because of the two minima, the energy levels for the nitrogen-hydrogen vibrations are split into two levels and that the nitrogen atom will tunnel through the plane of the three hydrogen atoms with a fixed frequency. The magnitude of the splitting for the several normal modes of vibration depends on the vibrational change in the height of the ammonia pyramid. Thus, the splittings are zero in the first approximation for the degenerate vibrations ω_3 and ω_4, essentially negligible for ω_1, but of great importance for ω_2.

Data for the fundamental vibrations, ω_1, ω_2, ω_3, and ω_4, were taken from Herzberg (*12*). The observed lower energy levels corresponding to ω_2 (in cm.$^{-1}$) were used as given in the lower range: 0, 0.66; 932.24, 968.08; 1597.4, 1910. Above this level a reassignment was made to give: 2380, 2840; 3305, 3770; 4235, 4700; etc., with a constant difference of 465 cm.$^{-1}$ in the higher levels. Trial-and-error calculations showed that negligible error was incurred using this difference. The lowest level corresponding to ω_1 is split slightly to give energies of 3335.9 and 3337.5 cm.$^{-1}$. Higher terms are also split, but are not of interest here.

A correction was made for rotational distortion (*35*) using a symmetry number of six. Several minor corrections were omitted, as the contribution from rotation-vibration interaction and Kassel's rotational partition function. Excellent agreement between calculated values and Osborne's experimental results was obtained without use of these corrections.

The moments of inertia for the ammonia molecule are those of Halverson (*10*). Fundamental physical constants are those used in most recent calculations (*31*) and the fundamental unit of heat is the defined or thermochemical calorie.

Values of the thermodynamic functions are given in Table 1 on the Kelvin temperature scale. Values on other temperature scales can be calculated using interpolation methods (*21*). Values

Table 1.—Thermodynamic Functions of NH_3 in the Ideal Gas State at One Atmosphere Pressure in °K.

Units: calorie, g-mole, ° K.

T, °K.	C°_p	$H^\circ - H^\circ_{273}$	$\frac{(H^\circ - H^\circ_0)}{T}$	S°	$\frac{T}{-(G^\circ - H^\circ_0)}$
233.16	8.180	−330.84	7.9951	43.984	35.989
243.16	8.222	−248.82	8.0036	44.328	36.324
253.16	8.268	−166.41	8.0130	44.660	36.647
263.16	8.318	− 83.487	8.0236	44.982	36.958
273.16	8.371	0	8.0355	45.293	37.258
291.16	8.472	151.31	8.0585	45.825	37.767
298.16	8.514	210.70	8.0685	46.026	37.958
300	8.526	226.60	8.0720	46.084	38.012
400	9.241	1113.6	8.2715	48.633	40.362
500	10.036	2077.6	8.5452	50.782	42.237
600	10.808	3120.1	8.8585	52.680	43.822
700	11.538	4237.8	9.1897	54.402	45.212
800	12.225	5426.3	9.5266	55.988	46.461
900	12.868	6681.3	9.8626	57.465	47.602
1000	13.467	7998.0	10.193	58.852	48.659
1100	14.021	9373.0	10.516	60.162	49.646
1200	14.530	10801.	10.830	61.404	50.574
1300	14.994	12277.	11.132	62.586	51.454
1400	15.414	13798.	11.424	63.713	52.289
1500	15.791	15359.	11.703	64.789	53.086

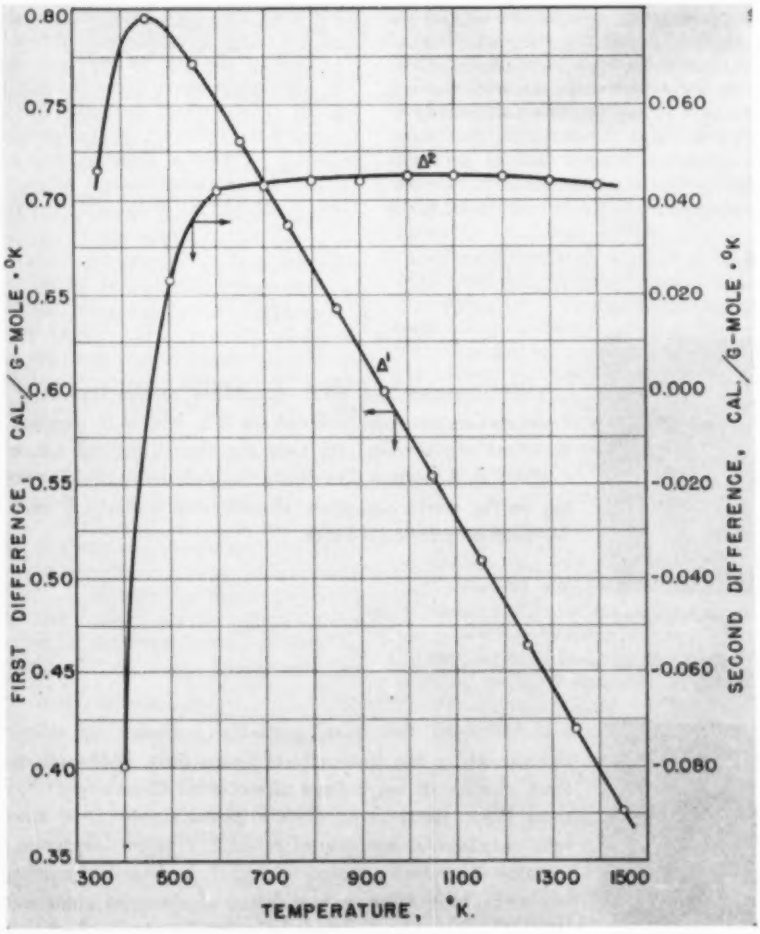


Fig. 1. First and second difference curves for the heat capacity of ammonia.

Table 2.—Empirical Constants for Heat-Capacity Equation for Ammonia

$$C_p^\circ = a + bT + cT^2 + dT^3$$

Temperature	a	b·10³	c·10⁶	d·10⁹	% Average deviation	% Maximum deviation
233–1500° K.	6.0864	8.8116	−1.5055	.....	0.55	1.48
233–1500° K.	6.5846	6.1251	2.3663	−1.5981	0.36	0.91
−40–1200° C.	8.3810	7.9891	−1.5055	.....	....	....
−40–1200° C.	8.4017	7.0601	1.0567	−1.5981	....	....

have been given to −40° C. because this temperature is used frequently as a reference point in refrigeration work. Enthalpy relative to the ice point, $H^\circ - H^\circ_{273}$, is used for enthalpy balances.

The heat-capacity values given are as accurate as the experimental values determined by Osborne *et al.*, who report an estimated average error of ±0.05% and a maximum error of ±0.55%. These correspond to 0.004 and 0.045 cal./(g.-mole)(K.°). The calculated values differ from the experimental by a maximum of 0.004 and an average of 0.002 over the entire range of temperature from −30 to 150° C. Since systematic procedures were used in the calculations, it is believed that the values are accurate outside the experimental range to 1500° K. Also, the difference curves obtained by subtracting succeeding values of heat capacity are smooth (Fig. 1). Another check on the accuracy of the data is the entropy at 25° C. The calculated value, 46.026 e.u., is within the limits of error of the Third Law value of 45.96 ± 0.10 e.u. as selected by Kelley (*17*).

Equations have been derived for the heat-capacity data using a least-squares method that gives the minimum percentage deviation (*19*). The constants are given in Table 2.

Ammonia Synthesis

Since the initial work of Haber and Van Oordt (*8, 9*) in 1904, many papers have appeared from European laboratories on the ammonia equilibrium (*6, 7, 14, 25*), concluding with a series of papers in 1915 by Haber and co-workers (*5*). Larson and Dodge determined the equilibrium values at temperatures from 350° to 500° C. and pressures from 10 to 1000 atm. (*22, 23*).

The ammonia-synthesis equilibrium is given by the equation:

$$1/2\ N_2(g) + 3/2\ H_2(g) \rightleftharpoons NH_3(g). \qquad (1)$$

The thermodynamic equilibrium constant for this reaction can be calculated from Equation (*2*).

$$-\frac{\Delta G^\circ}{T} = R \ln K \qquad (2)$$

The free energy change for the reaction can be calculated from the free energy functions of the products and reactants.

$$\frac{\Delta G^\circ}{T} = \left[\frac{G^\circ - H^\circ_o}{T} + \frac{(\Delta H^\circ_f)_o}{T}\right]_{product} - \Sigma\left[\frac{G^\circ - H^\circ_o}{T}\right]_{reactants} \qquad (3)$$

The heat of formation at 0° K., $(\Delta H^\circ_f)_o$, can be calculated from the heat of formation and the enthalpies, $H - H^\circ_o$, of ammonia, nitrogen and hydrogen at 298.16° K. as −9,374 cal./g.-mole. However, better agreement of the calculated and experimental equilibrium constants was found when the value $(\Delta H^\circ_f)_o = -9{,}254$ cal./g.-mole is used, which value was determined by Stephenson and McMahon (*33*) from experimental values of the equilibrium constants. Therefore, their value has been used to calculate the equilibrium constants as a function of temperature using free energy values of nitrogen and hydrogen from the most recent work (*30, 31*) and values for ammonia from Table 1. Calculated values of the equilibrium constant for Equation (1) are given in Table 3 and shown in Figure 2. These values compare excellently with the experimental values of Haber (*5*) and Larson and Dodge (*22, 23*) as corrected to the ideal gas values by Stephenson and McMahon (*33*).

The graph of log K against the reciprocal of the absolute temperature shows that the relationship is not linear. An equation of standard form containing five constants was derived, using a

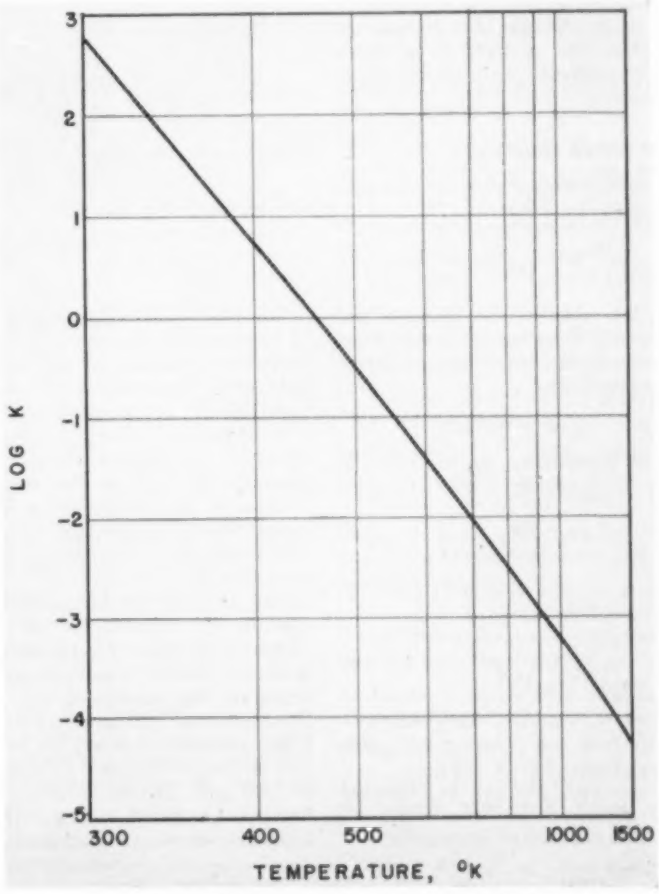


Fig. 2. Equilibrium constant for the ammonia synthesis.

Table 3.—Equilibrium Constants for the Ammonia Synthesis

$$\frac{1}{2}N_2 + \frac{3}{2}H_2 \rightleftharpoons NH_3$$

T, K°	Log K	K
298.16	2.83062	677.
300	2.78246	606.
400	0.75038	5.628
500	−0.52178	0.3008
600	−1.39940	0.03987
700	−2.04342	0.009048
800	−2.53646	0.002908
900	−2.92783	0.001181
1000	−3.24477	0.0005692
1100	−3.50578	0.0003121
1200	−3.72488	0.0001884
1300	−3.91091	0.0001228
1400	−4.07197	0.00008473
1500	−4.21177	0.00006141

method to give a minimum percentage deviation (*19*), Equation (4).

$$\log K = \frac{2250.322}{T} - 0.85340 - 1.51049 \log T - 25.8987 \times 10^{-5}T + 14.8961 \times 10^{-8}T^2 \quad (4)$$

This equation has an average deviation of 0.00055 and a maximum deviation of 0.0016 in log K over the temperature range from 500° to 1300° K. in which ammonia synthesis and decomposition are important.

Effect of Process Variables

The equilibrium constant for Equation (1) is given by Equation (5).

$$K = \frac{(a_{NH_3})}{(a_{N_2})^{1/2}(a_{H_2})^{3/2}} \quad (5)$$

Using the notation of Hougen and Watson (*13*) Equation (6) can be written for the calculation of the activity of any component B.

$$a_B = f_B = N_B f_{B\pi} = N_B \nu_{B\pi} \pi \quad (6)$$

The mole fraction N_B can be calculated from the total number of moles present:

$$N_B = \frac{n_B}{n_{N_2} + n_{H_2} + n_{NH_3} + n_{inert}} \quad (7)$$

A term K_ν can be calculated from the fugacity coefficients, $\nu_{B\pi}$:

$$K_\nu = \frac{\nu_{NH_3}}{(\nu_{N_2})^{1/2}(\nu_{H_2})^{3/2}} \quad (8)$$

Values of K_ν can be read directly, or calculated from generalized charts given by Hougen and Watson (*13*).

Previous equations can be combined to give Equation (9) from which all equilibrium calculations were made.

$$K = \frac{n_{NH_3}}{(n_{N_2})^{1/2}(n_{H_2})^{3/2}} \cdot K_\nu \cdot \frac{n_{N_2} + n_{H_2} + n_{NH_3} + n_{inert}}{\pi} \quad (9)$$

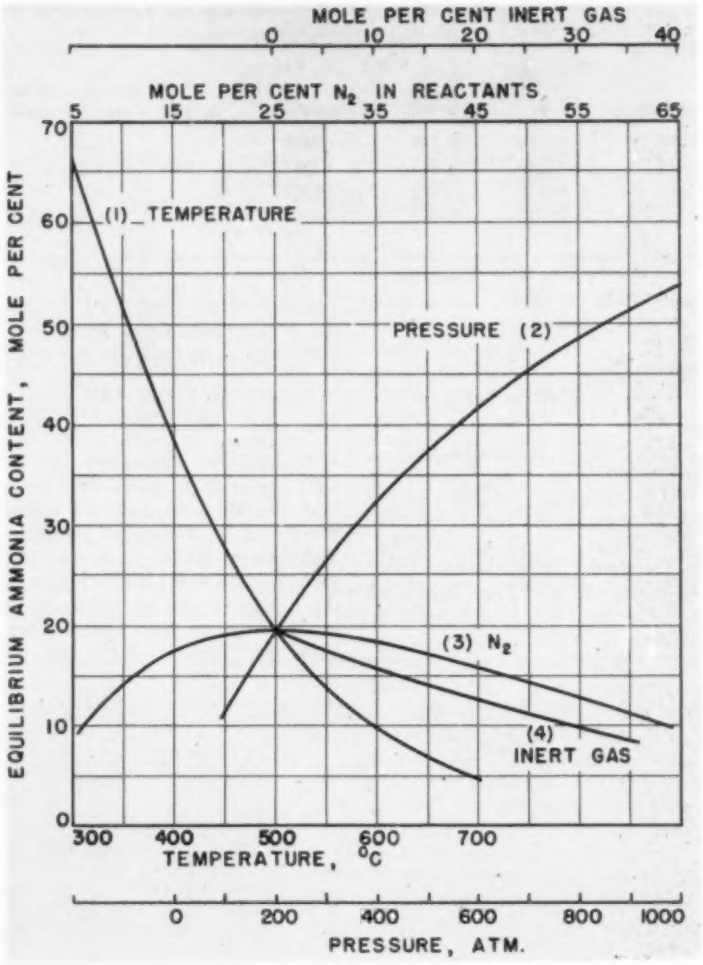

MOLE PER CENT INERT GAS
0 10 20 30 40
MOLE PER CENT N_2 IN REACTANTS
5 15 25 35 45 55 65
EQUILIBRIUM AMMONIA CONTENT, MOLE PER CENT
70 60 50 40 30 20 10 0
(1) TEMPERATURE
PRESSURE (2)
(3) N_2
(4) INERT GAS
300 400 500 600 700
TEMPERATURE, °C
0 200 400 600 800 1000
PRESSURE, ATM.

Fig. 3. Equilibrium relationships in the synthesis of ammonia.

The process variables considered for this reaction are temperature, pressure, excess nitrogen and the pressure of an inert gas. Their effects are shown in Figure 3 and are tabulated in Table 4.

In Figure 3, curve (1) shows the effect of temperature change on the ammonia content of the equilibrium mixture at 200 atm. with a stoichiometric mixture of reactants (N_2:$3H_2$). The ammonia content decreases rapidly from 66 mole % at 300° to 4.76 mole % at 700° C. The low temperature, however, is not suitable for the process because of a low rate of reaction. High pressure is desirable, as curve (2) illustrates for the reaction at 500° C. and stoichiometric reactants. The equilibrium ammonia concentration rises from 10.9 mole % at 100 atm. to 53.8 mole % at 1000 atm. The initial nitrogen content is not a critical process variable, as

Table 4.—Effect of Process Variables on Equilibrium Ammonia Content

Temperature

N_2:$3H_2$ at 200 atm.

t° C.	NH_3 mole %
300	66.0
350	52.4
400	39.1
450	27.9
500	19.5
550	13.4
600	9.36
650	6.60
700	4.76

Pressure

N_2:$3H_2$ at 500° C.

p, atm.	NH_3 mole %
100	10.9
200	19.5
300	26.4
400	32.2
500	37.2
600	41.5
700	45.1
800	48.4
900	51.2
1000	53.8

Excess Reactants

at 200 atm. and 500° C.

Reactants mole % N_2	NH_3 mole %
5.66	9.45
17.4	18.4
25.0	19.5
33.3	18.7
41.2	16.7
50.0	14.1
65.0	9.11

Inert Gas

N_2:$3H_2$, at 200 atm. and 500° C.

Inert Gas mole %	NH_3 mole %
0	19.5
9.5	16.0
20.0	12.6
33.3	8.97

shown by curve (3) for the reaction at 500° C. and 100 atm. The presence of inert gases has a greater effect, as curve (4) indicates, where the presence of 30% inert gas causes a decrease of 50% in the equilibrium ammonia content.

Oxidation of Ammonia

Ammonia oxidation now produces practically all the nitric acid made in this country. The process (*18*) is divided into two sections: (*a*) the oxidation of ammonia, followed by (*b*) the oxidation and absorption of the oxides of nitrogen. The reactions which occur in the ammonia oxidation step are:

$$NH_3(g) + 5/4\,O_2(g) \rightarrow NO(g) + 3/2\,H_2O(g) \quad (10)$$

$$NH_3(g) + 3/4\,O_2(g) \rightarrow 1/2\,N_2(g) + 3/2\,H_2O(g) \quad (11)$$

$$NH_3(g) + 3/2\,NO(g) \rightarrow 5/4\,N_2(g) + 3/2\,H_2O(g) \quad (12)$$

$$NH_3(g) \rightleftharpoons 1/2\,N_2(g) + 3/2\,H_2(g) \quad (13)$$

In industrial practice the oxidation is carried out by passing the mixture of ammonia and air through a platinum gauze catalyst at approximately 1000° C. with a contact time of 0.0001 sec. Under these conditions reactions 11, 12, and 13 are retarded and reaction 10 predominates. The equilibrium constants for reactions 10, 11, and 12 are given in Table 5. Values of the free energy function given in Table 1 for ammonia are combined with values for thermodynamic functions given in recent circulars (*30, 31*). The equilibrium data given previously by Stephenson and McMahon (*33*) for reaction 10 differ sharply from those given here. A check showed that their values could not be calculated from their sources of data.

An interesting comparison would be the equilibrium constants for the oxidation of ammonia directly to nitrogen dioxide and nitric acid.

$$NH_3(g) + 7/4\,O_2 \rightarrow NO_2(g) + 3/2\,H_2O(g) \quad (14)$$

$$NH_3(g) + 2\,O_2 \rightarrow HNO_3(g) + H_2O(g) \quad (15)$$

The free energy functions for nitrogen dioxide (*4*) and nitric acid (*3*) are those of Giauque and co-workers, who also calculated the equilibrium constants for the oxidation of nitric oxide to nitrogen dioxide (*4*). From the equilibrium constants given in Table 5 it is seen that nitrogen is always the thermodynamically preferred product. At the lower temperature nitrogen dioxide is preferred, but above about 750° K. the nitric oxide is more stable. The probability of producing nitric acid by direct oxidation of ammonia is small.

Nitrous oxide can be produced by the direct oxidation of ammonia (*20*), Equation (16).

$$NH_3(g) + O_2(g) \rightarrow 1/2\,N_2O(g) + 3/2\,H_2O(g) \quad (16)$$

Its thermodynamic functions have been calculated by Pennington (*29*). Equilibrium constants for its formation by ammonia oxidation are given in Table 5. Its formation is as probable as that of nitric oxide provided a satisfactory catalyst for the reaction can be found.

Table 5.—Equilibrium Constants for the Formation of the Following Compounds from One Mole of Ammonia

T, K°	$N_2(g)$	$N_2O(g)$	$NO(g)$	$NO_2(g)$	$HNO_3(g)$
300	7.33×10^{26}	7.30×10^{47}	6.39×10^{41}	7.68×10^{47}	6.30×10^{29}
500	7.06×10^{24}	4.44×10^{29}	1.13×10^{29}	1.43×10^{29}	1.32×10^{14}
700	2.61×10^{23}	2.69×10^{20}	2.11×10^{19}	5.04×10^{19}	
900	1.49×10^{22}	7.36×10^{15}	3.80×10^{15}	9.94×10^{14}	
1100	6.71×10^{20}	9.12×10^{13}	1.54×10^{13}		
1300	3.18×10^{19}	8.85×10^{10}	3.36×10^{11}		
1500	6.19×10^{17}	2.95×10^{9}	2.00×10^{10}		

Literature Cited

1. Bradley, H. B., Ch. E. 362 Report, Univ. of Texas (Feb. 28, 1948).
2. Bryant, W. M. D., *Ind. Eng. Chem.*, **25**, 820 (1933).
3. Forsythe, W. R., and W. F. Giauque, *J. Am. Chem. Soc.*, **64**, 48 (1942).
4. Giauque, W. F., and J. D. Kemp, *J. Chem. Phys.*, **6**, 40 (1938).
5. Haber, F., *et al.*, I. *Z. Elektrochem*, **20**, 597 (1914); II. *Z. Elektrochem*, **21**, 89 (1915); III. *Z. Elektrochem*, **21**, 128 (1915); IV. *Z. Elektrochem*, **21**, 191 (1915); V. *Z. Elektrochem*, **21**, 206 (1915); VI. *Z. Elektrochem*, **21**, 228 (1915); VII. *Z. Elektrochem*, **21**, 241 (1915).
6. Haber, F., and R. Le Rossignol, *Ber.*, **40**, 2144 (1907).
7. Haber, F., and R. Le Rossignol, *Z. Elektrochem.*, **14**, 181 (1908).
8. Haber, F., and G. Van Oordt, *Z. anorg. Chem.*, **43**, 111 (1904).
9. Haber, F., and G. Van Oordt, *Z. anorg. Chem.*, **44**, 341 (1905).
10. Halverson, F., *Rev. Modern Phys.*, **19**, 87 (1947).
11. Haupt, R. F., and E. Teller, *J. Chem. Phys.*, **7**, 925 (1939).
12. Herzberg, G., "Molecular Spectra and Molecular Structure II. Infrared and Raman Spectra of Polyatomic Molecules," pp. 221-4, 294-7, D. Van Nostrand Co., Inc., New York (1945).
13. Haugen, O. A., and K. M. Watson, "Chemical Process Principles. Part II. Thermodynamics," John Wiley & Sons, Inc., New York (1947).
14. Jost, F., *Z. anorg. Chem.*, **57**, 414 (1908).
15. Justi, E., "Spezifische Warme, Enthalpie, Entropie und Dissoziation Technischer Gase," p. 106, J. Springer, Berlin (1938).
16. Kelley, K. K., *U. S. Bur. Mines Bull.*, **407**, 28 (1937).
17. Kelley, K. K., *U. S. Bur. Mines Bull.*, **477**, 70 (1950).
18. Kobe, K. A., "Inorganic Process Industries," pp. 235-38, 276-83, Macmillan Co., New York (1948).
19. Kobe, K. A., and C. W. Arnold, *Petroleum Refiner*, **30**, No. 4, 123 (1951).
20. Kobe, K. A., and P. D. Hosman, *Ind. Eng. Chem.*, **40**, 397 (1948).
21. Kobe, K. A., and R. E. Pennington, *Petroleum Refiner*, **30**, No. 6, 143 (1951).
22. Larson, A. T., *J. Am. Chem. Soc.*, **46**, 367 (1924).
23. Larson, A. T., and R. L. Dodge, *J. Am. Chem. Soc.*, **45**, 2918 (1923).
24. Mayer, J. E., and M. G. Mayer, "Statistical Mechanics," John Wiley & Sons, Inc., New York (1947).
25. Nernst, W., *Z. Elektrochem.*, **13**, 521 (1907).
26. Nernst, W., and K. Wohl, *Z. tech. Physik.*, **10**, 608 (1929).
27. Osborne, N. S., H. F. Stimson, T. S. Sligh, Jr., and C. S. Cragoe, *Nat. Bur. Standards* (U. S.), Sci. Paper No. 501, **20**, 65 (1925).
28. Overstreet, R., and W. F. Giauque, *J. Am. Chem. Soc.*, **59**, 254 (1937).
29. Pennington, R. E., "Some Thermodynamic Properties of Nitrous Oxide," Thesis for M.S. (Chem. Eng.), Univ. of Texas (1950).
30. Rossini, F. D., *et al.*, "Selected Values of Properties of Hydrocarbons," *Nat. Bur. Standards Circ.*, **461** (1947).
31. Rossini, F. D., *et al.*, "Selected Values of Chemical Thermodynamic Properties," *Nat. Bur. Standards Circ.*, **500** (1952).
32. Spencer, H. M., and G. N. Flanagan, *J. Am. Chem. Soc.*, **64**, 2511 (1942).
33. Stephenson, C. C., and H. O. McMahon, *J Am. Chem. Soc.*, **61**, 437 (1939).
34. Thompson, H. W., *Trans. Faraday Soc.*, **37**, 351 (1941).
35. Wilson, E. B., Jr., *J. Chem. Phys.*, **4**, 526 (1936).

Calculation of Leaching Operations

Equilibrium and Nonequilibrium Conditions

Edward G. Scheibel Hoffmann-La Roche, Inc., Nutley, New Jersey

A concept of the free solution and the solution adhering to the solid as two separate phases is developed to show the relationship between liquid-solid extraction and other types of diffusional operations such as absorption, distillation, and liquid-liquid extraction. When the amount of adhering solution is constant, this concept allows for the use of well-known and generally available charts for estimating the operating conditions. It is also particularly valuable in cases involving high degrees of recovery, which generally require large numbers of stages.

For the cases where the liquid adhering to the solid varies appreciably with solute concentration, a simple graphical method is described for calculation of equilibrium stages in leaching operations. Based on a definition of fractional efficiency analogous to the Murphree efficiency in distillation, the graphical method can also be readily applied to the determination of stage efficiency from data on the performance of leaching equipment. The application of the method allows a rigorous evaluation of fractional stage efficiency in leaching operations.

Edward G. Scheibel has been head of the chemical engineering department at Hoffmann-La Roche, Inc., since 1945. Prior to this, he had five years' experience in production as plant superintendent for H. C. Bugbird Co. and three years' design experience with M. W. Kellogg and Hydrocarbon Research. He received a D.Ch.E. from Polytechnic Institute of Brooklyn in 1943, where he was also an adjunct professor of chemical engineering from 1942 to 1952. He is now adjunct professor at Newark College of Engineering. He received the Junior Member Award of the A.I.Ch.E. in 1949.

The general term *solvent extraction* may imply the extraction of a material by means of a suitable solvent from either a solid or a liquid. In order to be specific, the term *leaching* is applied to solid-liquid extraction as distinguished from liquid-liquid extraction. Leaching would be a simple problem if the liquid could be completely separated from the solid. If adsorption effects were absent, all extraction, or leaching, operations could be carried out in a single treatment since, even when the diffusion through the solid is slow, the provision of adequate time of contacting would give complete recovery.

It is, of course, never possible completely to remove the solution from the solid, but the soluble material in this adhering solution may be removed by repeated extraction with fresh solvent. Extraction is most efficiently carried out by passing the solid and solvent countercurrently through a series of stages. These stages may consist of individual mixing and separating units, or they may be realized by passing the solid and solvent continuously through a series of stages, as in the Rotocel extractor (*6*), or through a single long chamber, as in the Kennedy extractor (*7*).

Methods of calculation have been proposed in numerous publications (*4*). Many of the methods require cumbersome calculations or complicated graphical construction to evaluate the necessary number of stages; also, no simple method is available for carrying out the calculations when the contacting in the stages is incomplete, so that the liquid

adhering to the solid is of a different composition from the main body of the liquid.

It is possible to simplify the calculation of leaching operations by considering the analogy to liquid-liquid extraction, which at the present time has been developed to a greater degree. The subsequent derivations are made in the nomenclature of liquid-liquid extraction to facilitate the comparison of the solid-liquid and liquid-liquid extraction. The same equations could be developed in the previous nomenclature of leaching operations, although the significance of the terms would not, in some instances, be apparent. In this analogy the liquid adhering to the solid is considered the heavy phase and the balance of the liquid is considered the light phase. When the solid exhibits no adsorptive forces for the solute and the solid and liquid are so intimately mixed that so-called equilibrium conditions are realized, the liquid adhering to the solid will have the same composition as the main body of the liquid. The distribution coefficient is then unity between the two hypothetical phases. On the other hand, if the solid tends to adsorb the solute or to retard its diffusion to the solution, as in the solvent extraction of vegetable oils from flakes, so that nonequilibrium then exists between the two phases, the distribution coefficient is less than unity. It should be noted that the concentration in the heavy phase is calculated considering all solute in the solid dissolved in the solution on the solid.

In the case of multiple batchwise leaching with fresh solvent, the well-known relationship

$$\frac{x_N}{x_0} = \frac{1}{\left(1 + \frac{LD}{H}\right)^N}$$

can be derived where x_N/x_0 is the fraction of the solute remaining on the solid after N extractions with L parts of fresh solvent. The amount of solution adhering to the solid is assumed a constant value of H in the same units as L, and, since equilibrium can usually be attained in this type of operation by providing sufficient mixing and time of contacting, the distribution coefficient D may be generally taken as unity. The equation can be solved from a chart developed by Underwood (*13*) for this method of operation.

Figure 1 shows the nomenclature and location for the various streams in a countercurrent stagewise leaching operation according to this same concept. It should be noted that any consistent units of H, L, x, and y may be used, but when H is taken as the weight of solution, which is the usual method of presenting the necessary basic data for leaching operations, it must include all the extractable material even though some is adsorbed on or trapped in the solid. In these units x and y are then expressed in weight fractions.

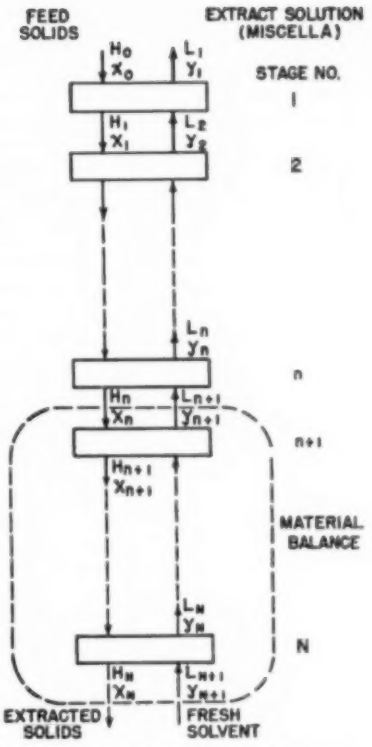


Fig. 1. Diagram showing material balance on continuous countercurrent leaching operation.

Equilibrium Extraction

The theoretical extraction stage is realized when all the solute is removed from the solid and is dissolved in liquid, which is then of uniform composition throughout. The quantity of solution adhering to the solid generally varies with the solute concentration, but, based on the assumption that H is constant throughout all the stages, alternate material balances and equilibrium calculations, as in liquid-liquid extraction, give the familiar relationship:

$$\frac{x_N - \frac{y_{N+1}}{D}}{x_0 - \frac{y_{N+1}}{D}} = \frac{E-1}{E^{N+1}-1} \qquad (1)$$

and when the fresh solvent is completely free of solute so that $y_{N+1} = 0$

$$\frac{x_N}{x_0} = \frac{E-1}{E^{N+1}-1} \qquad (2)$$

The left-hand side of this equation is the fraction of the solute remaining after N stages with an extraction factor of E. The equation is equivalent to that derived by Hawley (*5*) for leaching. However, this particular form has been represented graphically by Underwood (*13*) for convenient and rapid determination of any of the variables when the other two are established. The graph has been reproduced in numerous publications on liquid-liquid extraction. The fraction removed after N stages is given by $(E^{N+1} - E)/(E^{N+1} - 1)$ and this function has been reproduced graphically by the absorption factor charts (*11*), giving the fraction absorbed vs. absorption factor for different numbers of plates. These charts may also be used by substituting the extraction factor for the absorption factor. Based on this concept of leaching operations, the recovery of the solute from the solids can be rapidly determined from graphs already available.

When the solvent is not solute-free, y_{N+1} is generally negligible with respect to x_0, and the fraction unextracted is equal to the value of x_N/x_0 read from the chart plus y_{N+1}/x_0 since D is unity for an equilibrium leaching stage.

In some cases where the solute concentration of the liquid varies greatly, its effect on the physical properties of the solution may be great enough to produce an appreciable variation in the value of H. This situation requires experimental data to evaluate the quantity of liquid retained on the solid for different solute concentrations and is generally obtained by allowing a suspension to settle for a time equivalent to the residence time anticipated in each stage of the full-scale unit.

A solute material balance around the nth stage as shown in Figure 1 gives:

$$L_{n+1}y_{n+1} = H_n x_n - H_N x_N + L_{N+1}y_{N+1} \qquad (3)$$

A total material balance gives:

$$L_{n+1} = H_n - H_N + L_{N+1} \qquad (4)$$

and dividing the second equation into the first equation gives:

$$y_{n+1} = \frac{H_n x_n - (H_N x_N - L_{N+1}y_{N+1})}{H_n - (H_N - L_{N+1})} \qquad (5)$$

This equation is identical with that used as the basis for all previous methods of calculation of leaching operations and is given by other workers in different forms and nomenclatures. The equation in the present form indicates that, on a plot of Hx (the amount of solute retained with the solid) against H, y_{n+1} is the slope of a line between $(H_n, H_n x_n)$ and a second point whose ordinate is $H_N x_N - L_{N+1}y_{N+1}$ and whose abscissa is $H_N - L_{N+1}$. This second point is the same for all stages and is fixed by the conditions of the problem. The other point lies on the equilibrium curve determined experimentally, as

previously mentioned. On this figure the solute concentration in the solution x_n is the slope of a line between any point on the equilibrium curve and the origin. Since in an equilibrium stage $y_{n+1} = x_{n+1}$, a second line constructed through the origin with the same slope as the previous line locates the point $(H_{n+1}, H_{n+1}x_{n+1})$, and the construction can be repeated for the next stage. This method is illustrated in Figure 2 as applied to the leaching problem given by Badger and McCabe (*1*). The equilibrium curve, based on 2,000 lb. of meal, is plotted from the given data, and the location of point F is calculated according to the previous relationship. From the specifications of the problem $H_X x_X = 120$, $L_{X+1}y_{X+1} = 20$, $L_{X+1} = 1{,}330$ and from the equilibrium curve at $H_X x_X = 120$, H_X can be determined as 1,010. Thus the point F is located at $(-320, 100)$. Over-all solute and total material balances on the unit show that the concentration of oil in the miscella, or rich extract, must be $700/1{,}170 = 0.598$ to meet the specifications of the problem. Thus the line OA is constructed with a slope of 0.598 to intersect the equilibrium curve at point A, which represents equilibrium conditions in the first stage. Line AF is drawn and line OB is constructed parallel to AF by placing the transparent graph paper used for the figure over another paper containing a series of parallel lines at close intervals so that the line AF coincides with one of the lines. Point B may thus be located without actually drawing line OB, and this eliminates confusion on the figure when a large number of such equilibrium stage calculations must be made. Line BF is drawn, and the operations are repeated until the quantity $H_X x_X$ on the equilibrium curve is passed. In this case the point D on the equilibrium curve is slightly below the desired value of 120, and slightly less than four theoretical stages are required. This is in agreement with previous solutions of the same problem (*1* and *9*). The method of solution, like previous methods, is rigorous and is limited only by the scale and the accuracy of the construction.

In many cases it is desired to determine the amount of solvent required to give a specified recovery in a given number of stages or to determine the recovery obtainable in a given number of stages with a given amount of solvent. The solution of such a problem requires a trial-and-error procedure. However, the number of trials can be minimized by estimating an average value of H from the equilibrium curve and an average value of L consistent with this value of H to satisfy the over-all material balance on the unit. The use of these average values on the previously mentioned charts for Equations (1) and (2) gives a solution which may be used as the first trial in the rigorous graphical method.

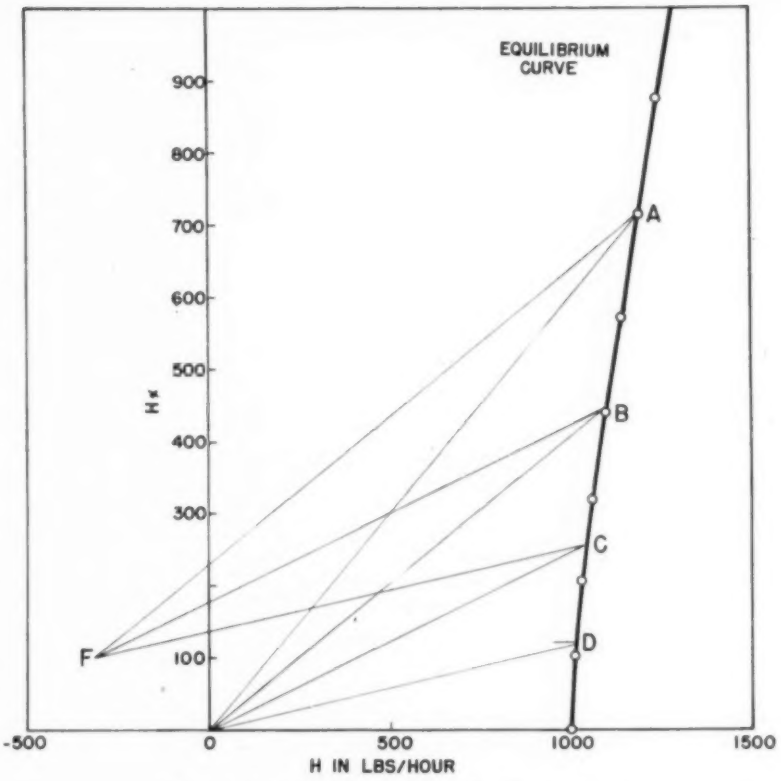


Fig. 2. Graphical calculations for equilibrium extractions.

Nonequilibrium Extraction

Theoretically, equilibrium between the solid and all the liquid can be realized only at infinite time. However, where the problem is primarily one of mixing the adhering solution with the extracting solvent, substantial equilibrium can be obtained in a reasonably short time. On the other hand, in the extraction of oil from ground meal or flakes, equilibrium is controlled by diffusion through the solid, and an appreciable time is required to attain equilibrium. It is useful therefore to define a stage efficiency function which will be a measure of the approach to equilibrium conditions. This is especially necessary in continuous countercurrent extractors, such as the Rotocel and Kennedy extractors, where residence time is limited. It has been shown both theoretically (*10*) and actually (*2*) that the fraction of an extractable solute removed at any time in a diffusion-controlling process is independent of concentration when the solute is in a liquid form. Piret et al. (*9*) have observed that this does not hold for the case of extraction of a solid, in which a liquid-solid interface recedes into a porous solid during the course of extraction. This phenomenon changes the concentration pattern in the porous solid so that the amount extracted varies in given manner, independent of the ultimate depth of the solid. In this case the amount of extraction cannot be fundamentally expressed as fraction of the total amount present.

Piret et al. (*9*) have derived the equation for the diffusion of a solid from capillary tubes when diffusion controls the rate process and the diffusivity is constant. They also derived the analogous equation for a porous sphere when the porous solid is completely inert and the porous structure is homogeneous, so that the pore-shape factor will be constant. Under some conditions this extraction will not deviate very greatly from a constant efficiency for a given time of contact, but this constancy is only fortuitous. Under such conditions, an observed stage efficiency of leaching equipment would have to be considered as an average value depending upon the concentration as well as the physical properties of the solid.

However, when all the solid has been dissolved, so that the process becomes one of pure diffusion through a liquid, it is possible to show that a stage efficiency defined as

$$e = \frac{x_n - x_{n+1}}{x_n - x^*_{n+1}} \qquad (5)$$

will be a constant in all stages if the time of contact in all stages is the same. This is the usual case. In this equation x_n is the concentration of the heavy phase entering the stage, x_{n+1} is the actual concentration leaving, and x^*_{n+1} would be the concentration in the heavy phase if equilibrium were reached. This definition is identical to the Murphree efficiency (8) used in distillation-column design. The application of this efficiency in distillation leads to an equivalent equilibrium curve proportionally located between the true equilibrium curve and the operating line so that the number of plates of fractional efficiency can be conveniently stepped off on the McCabe-Thiele diagram. Application of the definition to leaching calculations is also slightly more complex than with equilibrium stages. Several rigorous graphical techniques have been investigated by the present writer, the simplest of which utilizes a new focal point as well as an adjusted equilibrium curve, both of which are readily located.

Equation (5) can be solved for x_{n+1} as follows:

$$x_{n+1} = (1 - e)x_n + ex^*_{n+1} \qquad (7)$$

and since x^*_{n+1} is the concentration at equilibrium, it is equal to y_{n+1} as given by Equation (5). Substitution and rearrangement gives

$$x_{n+1} = \frac{[H_n - (1-e)(H_N - L_{N+1})]x_n - e(H_N x_N - L_{N+1}y_{N+1})}{H_n - (1-e)(H_N - L_{N+1}) - e(H_N - L_{N+1})} \qquad (8)$$

Inspection of this equation and comparison with Equation (5) indicates that x_{n+1} is the slope between a focal point located on the line OF in Figure 3 and a point on an adjusted equilibrium curve. The new focal point is located at a fractional distance of e from the origin, and the adjusted equilibrium curve is located by drawing a line through the origin to any point on the equilibrium curve and plotting the point on this line at a distance PQ from the abscissae of the equilibrium curve such that

$$PQ = MG = (1 - e)(H_N - L_{N+1}) \qquad (9)$$

It should be noted, however, that in the usual case, as illustrated in the figure, L_{N+1} is greater than H_N so that the point Q is located on the extension of line OP as shown. The graphical calculations are carried out with the focal point F' and the adjusted equilibrium curve as previously described until the ordinate value of $H_N x_N$ on the adjusted equilibrium curve is passed.

When the value of H is constant, the adjusted equilibrium curve is also a straight vertical line but somewhat farther from the origin. In this case, it is possible to derive a different relationship involving the original equilibrium curve and another readily located focal point. At constant H and L Equation (8) may be rearranged to

$$x_n = \frac{Hx_n - \dfrac{1}{1 + \dfrac{L}{H}\left(\dfrac{1-e}{e}\right)}(Hx_N - Ly_{N+1})}{H - \dfrac{1}{1 + \dfrac{L}{H}\left(\dfrac{1-e}{e}\right)}(H - L)} \qquad (10)$$

which indicates that the new focal which can be used with the actual equilibrium curve is on the line OF at a fractional distance

$$\frac{1}{1 + \dfrac{L}{H}\left(\dfrac{1-e}{e}\right)}$$

from the origin as shown on Figure 4.

As in the case of equilibrium extraction, the determination of any of the variables other than the number of actual stages of a given efficiency by this graphical method must be a trial-and-error procedure.

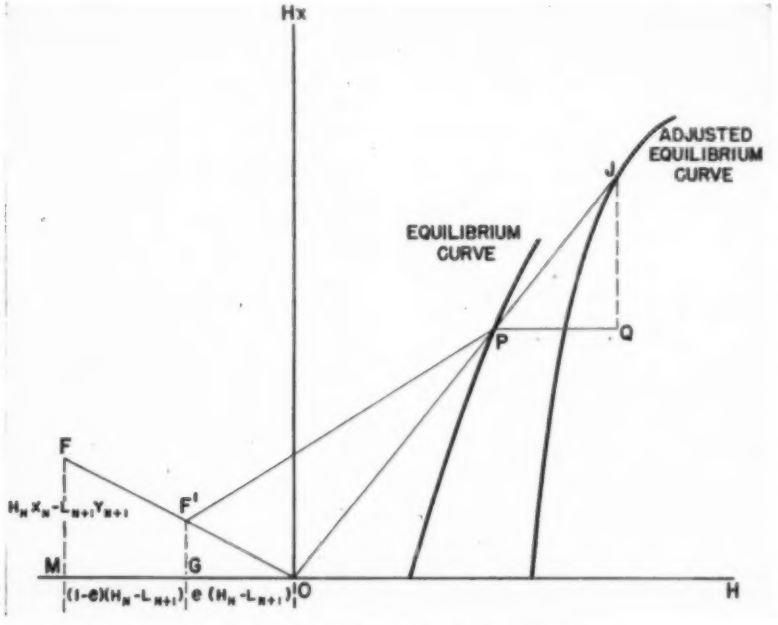


Fig. 3. Graphical calculations for fractional stage efficiency.

Application of the Graphical Method

In evaluating the stage efficiency from experimental performance data, the number of theoretical stages required to give the measured recovery of solute may be divided into the total number of actual stages to obtain an over-all stage efficiency. This efficiency is not necessarily the same as the individual stage efficiency but may be used as the first trial in the graphical method previously described. If the stagewise calculations at this fractional efficiency indicate more stages than the actual, a proportionately higher stage efficiency should be tried, and if the calculations indicate fewer stages, a proportionately lower stage efficiency should be used as the second trial. In general, the second trial will be in sufficiently close agreement with the actual number of stages so that additional trials will be necessary for only very precise work.

When the solid and liquid flow continuously countercurrent to each other, as in the Kennedy extractor (7), the concept of the height or length equivalent to a theoretical stage is immediately apparent. Also, based on the analogy to packed columns in absorption, distillation, and liquid-liquid extraction, a concept similar to the transfer unit would be more applicable. The number of transfer units is the integral of all the stages of differential efficiency and can be approached in the graphical method by assuming a low stage efficiency of 10 or 20% and multiplying the calculated number of actual stages by the assumed efficiency. The agreement between the true number of transfer units and the number so calculated will be better the lower the assumed stage efficiency, but for many practical purposes the use of a 20% stage efficiency will be sufficiently accurate.

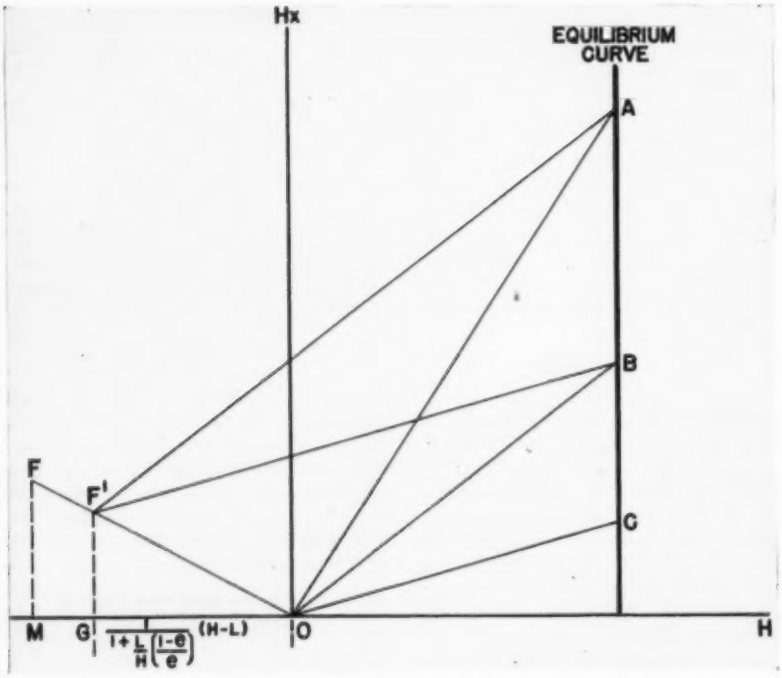


Fig. 4. Graphical calculations for fractional stage efficiency modified for constant *H*.

The methods developed in this work are presented with the hope that they will serve as a criterion for evaluating the performance of leaching equipment and thus stimulate publication of such data, which have been notably lacking in this field of chemical engineering information. The concept of the fractional stage efficiency may not be theoretically rigorous in some instances, but an average value properly determined over a suitable range of conditions could be used in full-scale design calculations with almost the same reliability as the Murphree plate efficiency is applied in distillation-design calculations.

Notation

D = distribution coefficient; ratio of concentration of solute in main body of solution to concentration in liquid adhering to solid = y/x
E = extraction factor = LD/H
e = stage efficiency expressed as a fraction
H = flow rate of solution adhering to solid (underflow)
L = flow rate of free solution
N = total stages
n = number of any stage
x = concentration of solute in solution adhering to solid, assuming any trapped or adsorbed solute also dissolved in solution
y = concentration of solute in free solution

Subscripts refer to flow quantities away from the particular stage.

Literature Cited

1. Badger, W. L., and W. L. McCabe, "Elements of Chemical Engineering," 2nd ed., p. 432, McGraw-Hill Book Company, Inc., New York (1936).
2. Boucher, D. F., J. C. Brier, and J. O. Osburn, *Trans. Am. Inst. Chem. Engrs.*, **38**, 967 (1942).
3. Chilton, T. H., and A. P. Colburn, *Ind. Eng. Chem.*, **27**, 225 (1935).
4. Elgin, J. C., and R. Wynkoop, in "Chemical Engineers' Handbook," 3rd ed., edited by J. H. Perry, p. 746, McGraw-Hill Book Company, Inc., New York (1950).
5. Hawley, J., *Ind. Eng. Chem.*, **9**, 866 (1917).
6. Karnofsky, G., *Chem. Eng.*, **57**, 109 (August, 1950).
7. Lerman, F., A. B. Kenne[illegible], and J. Loshin, *Ind. Eng. Chem.*, **40**, 1753 (1948).
8. Murphree, E. V., *Ind. Eng. Chem.*, **17**, 747, 960 (1925).
9. Piret, E. L., R. A. Ebel, C. T. Kiang, and W. P. Armstrong, *Chem. Eng. Prog.*, **47**, 405, 628 (1951).
10. Ruth, B. F., *Chem. Eng. Prog.*, **44**, 71 (1948).
11. Sherwood, T. K., *Ind. Eng. Chem.*, **21**, 976 (1929).
12. Sherwood, T. K., "Absorption and Extraction," p. 85, McGraw-Hill Book Company, Inc., New York (1937).
13. Underwood, A. J. V., *Ind. Chemist*, **10**, 128 (1934).

Discussion

John Griswold (General Chemical Division, New York, N. Y.): This is an ingenious method for applying solvent-extraction calculations to leaching. It will be a great help in leaching calculations, particularly for nonequilibrium conditions. In solvent extraction the calculations are rigorous in terms of phase equilibria and the diffusional mechanism, which means linear driving force on each side of the two liquid interfaces. These premises have been carried over into leaching. H is taken as the flow rate of the heavy liquid. Actually, it is some function of the solid material. X, the concentration in that hypothetical heavy liquid, is related to the concentration in the solids material. H and x therefore are both somewhat hypothetical quantities. In the equations in this paper H and x sometimes appear together and sometimes separately. Where there is actually equilibrium at a stage, the positions of H and x make no difference; the calculations will come out 100% correct. Where there is no equilibrium, a different mechanism prevails, in a number of cases at least, of the solute moving from inside the particles out to the surface and then across the interface into the other stream. There are two cases in particular that I can think of. One is in drying, where the solute is a liquid and moves by capillarity, at least in part. The other is in the case of adsorption of material on a solid, where some kind of an adsorption isotherm applies and the exponent on the concentration term is not unity. In either case the concentration gradient or the driving force for mass transfer will not be linear. Where the mass-transfer resistance in the solid is controlling, we will run into difficulty in applying these equations for solvent extraction to leaching because the assumptions are not fulfilled. That will show up in values of e, the extraction efficiency not being constant throughout the equipment but actually varying in a somewhat complicated manner. I think that the special condition of leaching can be accounted for in terms of a constant stage efficiency, but the equations when they are developed will be considerably more complicated than those being considered at present (*1*). Possibly Dr. Scheibel has anticipated this to some extent.

E. G. Scheibel: One point I want to stress. It was brought out in the paper that the definition of e goes back to the previous derivations and that it assumes that all the solute in the solid, whether it is on the liquid adhering to the solid or actually in the main body of the solid, must be included in the value of Hx. The total solute-extractable material retained on the solid must be assumed to be included in the value of H to give the composition x. That makes the definition rigorous in the case of the extraction of liquids from insoluble solids. Of course it does not make it rigorous for the extraction of solids from insoluble solids.

Literature Cited

1. Piret, E. L., R. A. Ebel, C. T. Kiang, and W. P. Armstrong, *Chem. Eng. Progress*, **47**, 405, 628 (1951).

Experimental Reaction Rates in the Synthesis of Ammonia

R. M. Adams and E. W. Comings University of Illinois, Urbana, Ill.

In a study of the continuous synthesis of ammonia, a catalytic converter was designed for operation at pressures of 15,000 lb./sq.in. at temperatures up to 500° C. The catalyst volume was 0.061 cu. in. Three hundred isothermal runs were made with three ammonia-free mixtures of hydrogen and nitrogen at 100, 200, and 300 atm. at 350° to 500° C. and at space velocities from 10,000 to 125,000 hr.$^{-1}$ The per cent of ammonia in the exit gases was determined, and the reaction rates were calculated from this. Applications to reactor design and reaction mechanism are discussed.

The synthesis of ammonia from nitrogen and hydrogen over doubly promoted iron catalysts has been the subject of intensive study; yet only a small amount of data relating the rate of synthesis to space velocity, temperature, pressure, and gas composition is available in chemical and engineering literature. The most extensive measurements are those reported by Emmett and Kummer (*3*) for pressures up to 100 atm. and temperatures between 370° and 475° C. This paper presents new experimental data on the isothermal synthesis at 100, 200, and 300 atm.

Experimental

THE APPARATUS

A schematic diagram of the apparatus is shown in Figure 1. Hydrogen and nitrogen from commercial cylinders were mixed in the desired proportions in a gas holder. The mixture was drawn from the holder and compressed by a three-stage gas compressor and hydraulic booster compressor. The compressed gas was stored in two forged-steel cylinders at pressures of several hundred pounds per square inch higher than the pressure in the remaining part of the system. A needle valve between the storage cylinders and the reaction system was used to maintain a constant pressure in the reactor for a given rate of flow through the catalyst bed. From storage, the gas entered the purifying train where oxygen, water vapor, carbon dioxide, dust, and oil were removed. The pure gas passed into the reactor and through the catalyst. The gaseous products were reduced to atmospheric pressure in one stage by a needle valve, and the ammonia was scrubbed out. The ammonia-free gas escaped to the atmosphere.

The reactor was constructed of S.A.E. 6150 chrome-vanadium steel and was designed to withstand an internal pressure of 15,000 lb./sq.in. at 500° C. The steel had a yield point of 106,000 lb./sq.in. at 700° F. and an ultimate strength of 128,000 lb./sq.in. at 700° F. The design was based on Lame's equations and the maximum strain theory of elastic failure. The inside diameter of the reactor was 1.625 in. and the outside 5 in.; the over-all length was 17 in.

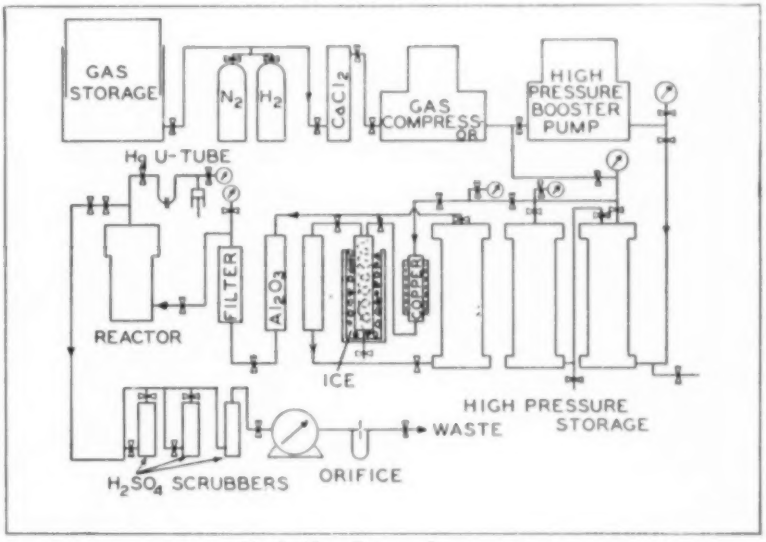


Fig. 1. Flow diagram of apparatus.

Figure 2 is a simplified diagram of the reactor and its internal parts. The cold gas feed entered through the bomb wall at a point near the bottom of the reactor and was directed by means of a copper inner tube up along the inside walls of the vessel. The gas then passed down over an electric heating coil and up again through the catalyst bed and out of the reactor. The heater was wound more closely near the head of the bomb than lower on the catalyst support tube in order to decrease the temperature gradient caused by the flow of heat along the tube to the bomb head.

The catalyst chamber was made of copper and had a volume of 0.061 cu.in., or 1 ml. (0.38 in. in diam. by 0.5 in. long), when the thermocouple assembly was in place. Three iron-constantan thermocouples were inserted in the catalyst bed,

Mr. Adams's present address is Minnesota Mining and Mfg. Co., St. Paul 6, Minnesota; Mr. Comings is at Purdue University, Lafayette, Indiana.

one at the bottom of the bed, another just above the top of the bed, and a third in a catalyst pellet at the center of the bed. Heat transfer in the area of the catalyst bed was sufficiently good to maintain the readings of the three thermocouples within a range of 1 to 3 degrees, the two lower couples usually being within 1 degree of each other. The temperature of the catalyst bed was controlled by regulation of the power input to the heater, so that the heat loss from the bomb kept the bed at the required temperature.

Purification of the gases was accomplished by passing them successively through a hot copper gauze deoxidizer, ice condenser, soda-lime tower, magnesium perchlorate tower, ballast cylinder, activated-alumina tower, and sand filter. Ammonia in the effluent gas mixture was removed by scrubbing with standard sulfuric acid in fritted glass absorption cylinders. No gas was recirculated, and the effect of inert gases was not investigated.

The reactor pressure was measured with a Bourdon-tube-type gauge calibrated at intervals against a dead-weight gauge.

EXPERIMENTAL PROCEDURE

The catalyst used for the experiments was provided by the American Cyanamid Co. and had the following chemical analysis:

Fe_2O_3	66.76%
FeO	28.70
Al_2O_3	2.84
K_2O	1.04
SiO_2	0.26

The catalyst was screened before use to obtain particles which passed 5-mesh screen but were retained on 6-mesh. This treatment gave fairly uniform catalyst pieces whose maximum dimension in any one direction was about ⅛ in. Enough of these pieces were loosely placed in the catalyst chamber just to fill its 1-ml. volume.

The reduction of the oxides to an activated catalyst was accomplished with difficulty. Unsuccessful attempts were made to reduce several different catalyst charges. Finally, careful examination of the reactor revealed carbon deposits in the vessel. These apparently came from the cracking of minute oil droplets picked up by the gas from oil films on the tubing walls. On this supposition, a fine sand filter was inserted in the system just ahead of the reactor for the purpose of removing such aerosols. Following this modification of the apparatus, a fresh catalyst charge was reduced which exhibited an activity several times greater than that shown by any previous sample. This last charge was reduced at 100 atm. at a space velocity of 5,000 hr.$^{-1}$ for the first half of the reduction period and at a space velocity of 10,000 for the remaining half. The reduction required about 73 hr., during which time the catalyst was heated at a substantially constant rate from room temperature to 450° C. with 8-hr. heating arrests at 250° and 350° C. Forty-eight hours after the appearance of the first trace of ammonia in the effluent gases, analyses showed the catalyst to have a constant activity.

The composition of the gases entering the reactor was determined daily by measuring the volumes of a gas sample before and after the removal of hydrogen by hot copper oxide. Variation in the initial gas composition from day to day was never more than 5% and was usually less than 2% from the desired value.

A single charge of catalyst and one activation of this catalyst was used for all the runs reported here. The results represent the action of this one charge under the conditions prevailing in the reactor, and different results would be expected from a different catalyst. In general, runs were made from low to high space velocities and back. Conditions used in earlier runs were repeated at intervals as a check on the constancy of the catalyst activity. The results indicated that the activity of the catalyst was substantially constant throughout the experiments.

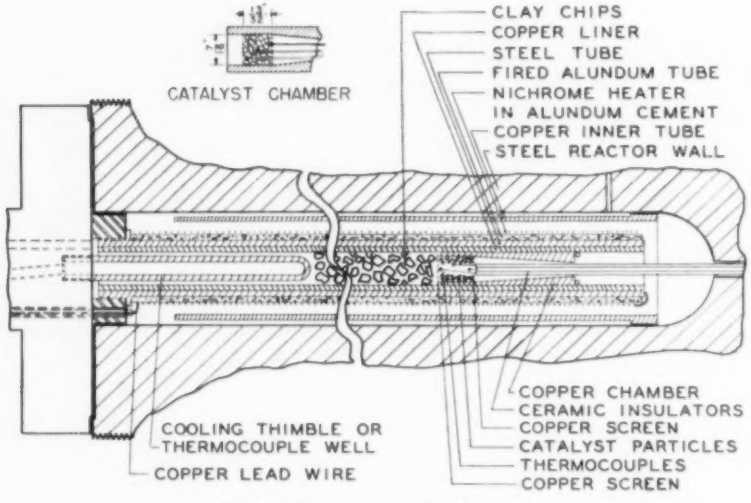


Fig. 2. Interior arrangement of reactor.

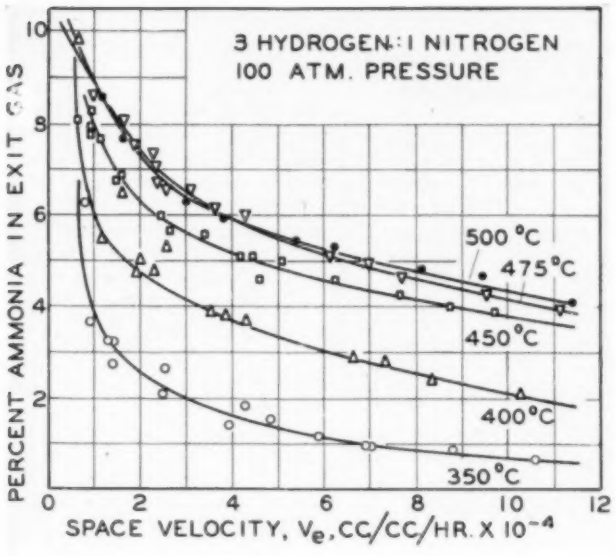
Results

A total of 300 isothermal runs were made (*1*) with three ammonia-free mixtures of hydrogen and nitrogen at 100, 200, and 300 atm. from 350° to 500° C. and at space velocities of 10,000 to 125,000 hr.$^{-1}$ The results of these runs are shown in Figures 3 through 6. Each of the curves in these figures shows the ammonia content of the exit gas for a range of space velocities at a given temperature, pressure, and initial gas composition. Figure 3 represents the results from a 3- to 1-molal hydrogen to nitrogen ratio at 100 atm. pressure and at five temperatures. Figures 4 and 5 differ from Figure 3 only in the pressure, which was 200 and 300 atm. respectively in these two figures. The curves in these figures should extrapolate to the equilibrium gas composition at a space velocity of zero. At equilibrium the per cent of ammonia will be higher for lower temperatures. In these three figures the per cent of ammonia is usually higher at the higher temperatures, an indication that the rate of reaction rather than equilibrium is the limiting factor in these tests. An exception to this statement is evident in Figure 5. In the runs at 300 atm. the curves for 475° and 500° C. cross. A higher per cent of ammonia is obtained at 475° C. with low space velocities, while at high space velocities the higher per cent of ammonia is at 500° C. In the first case the effect of equilibrium is apparent and seems to be the limiting factor, while in the second case the rate of reaction is controlling.

In Figures 4 and 6 the three separate initial gas compositions are shown. For mixtures containing more than 25% nitrogen and for a given temperature, pressure and space velocity, the per cent of ammonia in the exit gases decreases as the per cent of nitrogen in the gases to the converter increases.

Mechanism of the Reaction

A number of attempts have been made to determine the mechanism by which



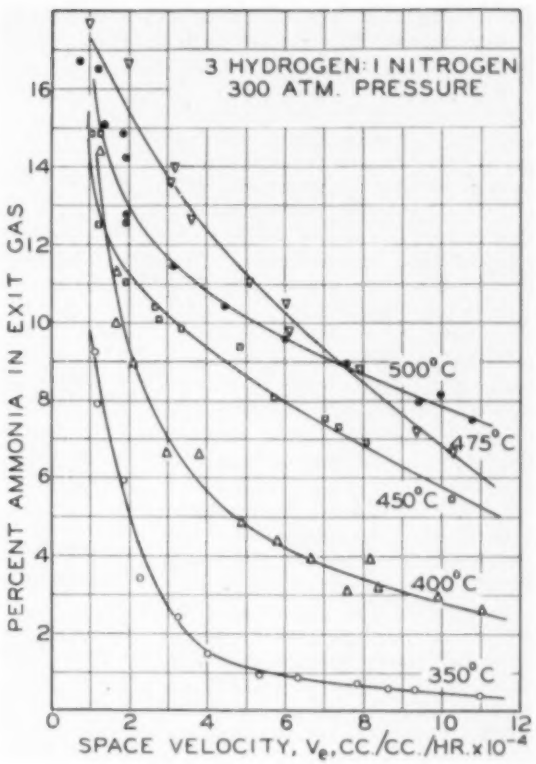
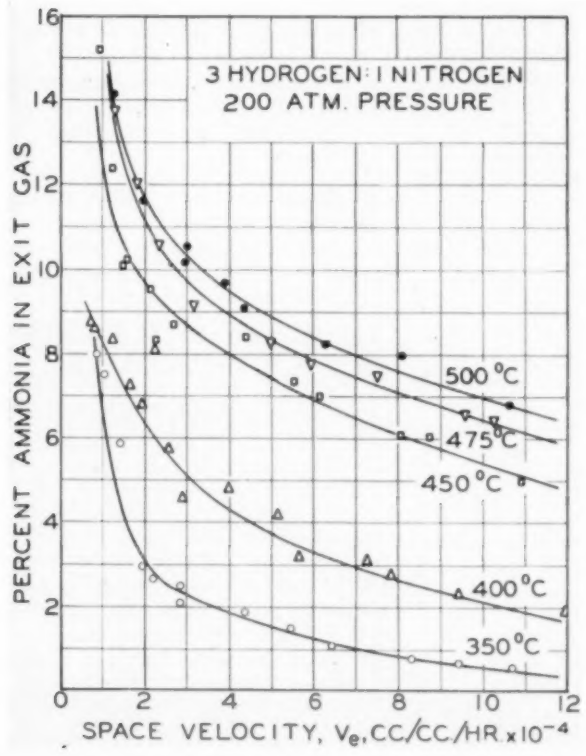
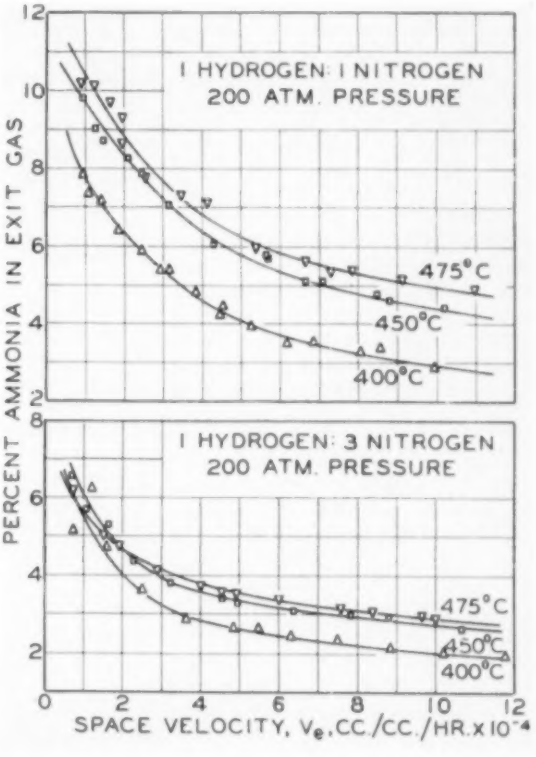


Fig. 3. Top left, Per cent ammonia in exit gas vs. space velocity at 100 atm.
Fig. 4. Bottom left, Per cent ammonia in exit gas vs. space velocity at 200 atm.
Fig. 5. Top right, Per cent ammonia in exit gas vs. space velocity at 300 atm.
Fig. 6. Bottom right, Per cent ammonia in exit gas vs. space velocity at 200 atm.





nitrogen and hydrogen combine on a doubly promoted iron catalyst to form ammonia. One of the more recent is that of Temkin and Pyzhev (*12*). Using equations for the rate of adsorption and desorption of nitrogen on iron, these investigators derived an expression for the rate of synthesis of ammonia based on their proposed mechanism. The theories of Temkin and Pyzhev were applied by Emmett and Kummer (*3*) to measurements made at the Fixed Nitrogen Research Laboratory. The agreement between their theory and the experimental results, though not good, gave some support to the fundamental assumptions and general conclusions. On the basis of the promise shown by these earlier experiments, the kinetics of Temkin and Pyzhev were applied to the data reported here. Agreement between theory and experiment was even less satisfactory than that obtained by Emmett and Kummer.

Temkin and Pyzhev expressed the equilibrium constant and rate equations in terms of partial pressures and made no allowance for the compressibility of the gases at high pressures. Their derivations were modified, and both the activity of the gases and their compressibility taken into account. Emmett and Kummer point out that these authors assumed that the adsorption of nitrogen on iron in the presence of an ammonia-hydrogen mixture is the same as it would be when at equilibrium with the partial pressure of nitrogen equivalent to the existing partial pressure of ammonia and hydrogen in the gas mixture. This equilibrium is expressed in terms of activities by the equation

$$K = \frac{a^2_{NH_3}}{a^3_{H_2} a_{N_2}} = \frac{a^2_{NH_3}}{a^3_{H_2} a^*_{N_2}} \qquad (1)$$

where $a^*_{N_2}$ is the activity of nitrogen in equilibrium with the nitrogen adsorbed on the catalyst. At pressures up to 300 atm. the activity may be expressed as $a = nPv$ according to the Lewis and Randall fugacity rule. At higher pressures this rule leads to increasingly larger errors (*5*). Thus if the equivalent partial pressure of the adsorbed nitrogen is $P^*_{N_2}$ and this is related to the activity by the expression $a^*_{N_2} = v_{N_2} P^*_{N_2}$, then

$$P^*_{N_2} = \frac{n^2_{NH_3} K_v}{n^3_{H_2} PK} \qquad (2)$$

This pressure is substituted in the adsorption equation as described by Emmett and Kummer, and the equation for the rate of ammonia synthesis becomes

$$\frac{1}{2}\frac{dN_{NH_3}}{dt} = k_a W n_{N_2} P (b_o K_v/PK)^{-1/2} - \frac{n^{1.5}_{H_2}}{n_{NH_3}} - k_d W (b_o K_v/PK)^{1/2} \frac{n_{NH_3}}{n^{1.5}_{H_2}} \qquad (3)$$

At equilibrium the rate of ammonia synthesis is zero and

$$k_a = k_d \frac{b_o K_v}{P^2 K} \frac{n^2_{NH_3}}{n^3_{H_2} n_{N_2}} = k_d b_o \qquad (4)$$

For convenience this may be written as

$$\frac{k_a}{b_o^{1/2}} = k_d b_o^{1/2} = k \qquad (5)$$

The mole fractions of nitrogen, hydrogen, and ammonia may be expressed in terms of the per cent of ammonia in the gas z. It is convenient to do this on the basis of the stoichiometric ratio of hydrogen to nitrogen, i.e., 3 to 1. In such a mixture the mole fraction of hydrogen is 0.75. Let a be the ratio of the mole fraction of hydrogen in any mixture of hydrogen and nitrogen to that in the 3-to-1 mixture. Then after ammonia has been formed in the mixture, the mole fraction of each component is

$$n_{NH_3} = z \qquad (6)$$

$$n_{H_2} = \frac{3}{4}[a(1+z) - 2z] \qquad (7)$$

$$n_{N_2} = \frac{1}{4}[4 - 3a(1+z) + 2z] \qquad (8)$$

where, for example, $a = 1$ for $3H_2:1N_2$, $a = 2/3$ for $1H_2:1N_2$, and $a = 1/3$ for $1H_2:3N_2$, etc.

In the case of steady flow through a catalyst bed, let N_o be the moles of hydrogen-nitrogen mixture equivalent to the mixture of hydrogen-nitrogen-ammonia in the volume of the catalyst W. The moles of ammonia in the mixture will be N_{NH_3} and the total moles will be $N_o - N_{NH_3}$, since each mole of ammonia was formed from 2 moles of hydrogen-nitrogen mixture. Then

$$z = \frac{N_{NH_3}}{N_o - N_{NH_3}} \qquad (9)$$

$$dN_{NH_3} = N_o \frac{dz}{(1+z)^2} \qquad (10)$$

$$N_o = \frac{\phi P (1+z) W}{CRT} \qquad (11)$$

where

ϕ = fraction of voids in catalyst volume W

C = compressibility factor.

If the volume of catalyst is increased by an infinitely small amount dW, the resultant increase in contact time is

$$dt = \frac{273 C_s P \phi (1+z)}{C U_o T} dW \qquad (12)$$

where

C_s = compressibility factor at standard conditions

U_o = volume of nitrogen-hydrogen mixture (at standard conditions) entering the catalyst bed per unit time.

By the definition of the space velocity based on the entering gases

$$d\left(\frac{1}{V_o}\right) = \frac{dW}{U_o} \qquad (13)$$

where V_o = space velocity based on unreacted hydrogen-nitrogen mixture. Equations (5), (6), (7), (8), (10), (11), (12), and (13) may be combined with Equation (3) to give

$$d\left(\frac{1}{V_o}\right) = \frac{P^{0.5} dz / 546 k R C_s (1+z)^2}{\left[\frac{\frac{1}{4}[4 - 3a(1+z) + 2z]}{z(K_v/K)} \left\{\frac{3}{4}[a(1+z) - 2z]\right\}^{1.5} P^2 - \frac{z(K_v/K)}{\left\{\frac{3}{4}[a(1+z) - 2z]\right\}^{1.5}}\right]} \qquad (14)$$

Integrating and rearranging

$$k' = 546 k R C_s$$

$$= V_o P^{0.5} \int_o^z \frac{z\left\{\frac{3}{4}[a(1+z) - 2z]\right\}^{1.5} dz}{(1+z)^2 \left[\frac{1}{4}[4 - 3a(1+z) + 2z]\left\{\frac{3}{4}[a(1+z) - 2z]\right\}^3 P^2 \frac{K}{K_v} - z^2 \frac{K_v}{K}\right]} \qquad (15)$$

TABLE 1. Values of k' from Equation (15)

P	V_s	3 hydrogen to 1 nitrogen					1 hydrogen to 1 nitrogen			1 hydrogen to 3 nitrogen		
atm.	$hr.^{-1}$	350° C.	400° C.	450° C.	475° C.	500° C.	400° C.	450° C.	475° C.	400° C.	450° C.	475° C.
100	25000	54.5	890	6030	14800	29000						
	50000	40.3	1030	8190	18400	36300						
	75000	24.8	960	9190	19600	40000						
	100000	20.2	836	9970	19900	40500						
200	25000	30.1	570	5400	13900	24600	572	3260	7180	409	1970	4200
	50000	20.1	496	2980	15300	31600	551	3600	8050	424	2380	5150
	75000	10.9	409	7290	17200	34900	549	3820	8550	491	2790	6110
	100000	4.41	299	7050	17500	36600	562	4110	9880	519	3120	6560
300	25000	1.98	437	2940	9950	12200						
	50000	.37	308	3780	11400	16700						
	75000	.22	252	3760	10400	18500						
	100000	.12	206	3220	7930	19300						

Equation (15) is a general mathematical expression for the theory of Temkin and Pyzhev as applied to the isothermal reaction. The soundness of the theory may be tested by calculating values of k' from experimental data which cover an adequate range of space velocity, temperature, total pressure, and initial gas composition. For a given temperature, k' should remain constant for varying space velocity, pressure, and gas composition within the experimental errors of the data.

Values of k' calculated from Equation (15) are shown in Table 1.

Temkin (*11*) discusses the effect of compressibility and derives the instantaneous rate equations in terms of fugacities. He compares these equations with the measurements of Sidorov and Livshits (*9*) on the ammonia synthesis reaction at 300 atm. with a 3 hydrogen to 1 nitrogen gas. These measurements were not extensive enough to demonstrate that the theory predicts the effects of pressure and composition with a single catalyst.

The discussion in this section makes no allowance for differences between the mole fraction of nitrogen, hydrogen, and ammonia in the gas mixture and adjacent to the catalyst surface. Justification of this will be discussed in the next section.

In view of the considerable variation in k' with pressure, it is concluded that efforts to correlate the kinetics of the formation of ammonia with the mechanism for its synthesis are not entirely satisfactory over the entire operating range of these variables. However, the lack of a quantitative expression for the rate of synthesis as a function of gas composition, pressure, space velocity, and temperature does not prevent the rational design of a commercial reactor based on measurements of the type shown in Figures 3 through 6. For design purposes, it is more convenient to express these data as rates of formation. This conversion is readily accomplished in the case of the ammonia synthesis.

Rates of Ammonia Formation

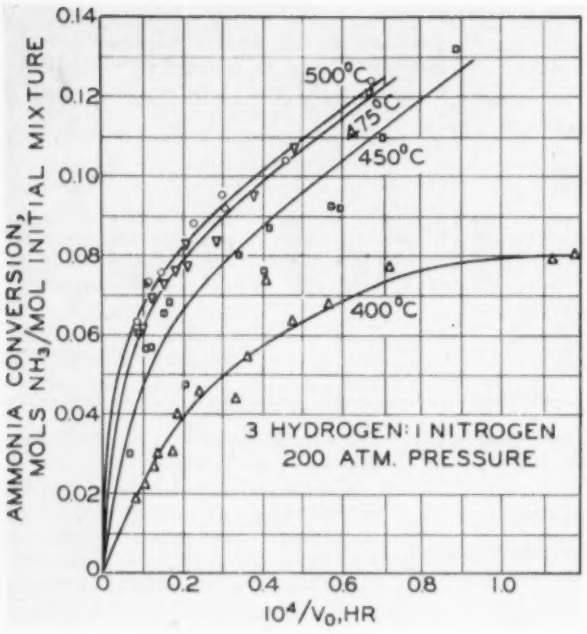
The mechanism of a solid-catalyzed-gas reaction involves, according to Hougen and Watson (*6*):

1. The mass transfer of reactants and products to and from the gross exterior surface of the catalyst particle and the main body of the fluid.
2. The diffusional and flow transfer of reactants and products in and out of the pore structure of the catalyst particle when reaction takes place at interior interfaces.
3. The activated adsorption of reactants and activated desorption of products at the catalytic interface.
4. The surface reaction of adsorbed reactants to form activation adsorbed products.

The discussion in the preceding section assumed that the rate of activated adsorption of nitrogen as a part of Step 3 controls the rate of ammonia synthesis. The experimental verification of this assumption as given in this paper and elsewhere (*3* and *11*) is not conclusive. A method of reactor design based on a less restrictive assumption will be described.

Hurt (*7*) states that for the ammonia synthesis 15% of the resistance to reaction may be attributed to diffusional effects, while the remaining 85% may be attributed to the reaction on the catalyst surface. Gamson, Thodos and Hougen (*4*) have calculated the partial-pressure difference of nitrogen through the gas film from data of Larson and Tour (*8*) on the ammonia synthesis. At 100 atm. total pressure they found the average partial-pressure drop of nitrogen through the gas film to be less than 0.005 atm., indicating an almost negligible resistance to mass transfer. Wheeler (*13*) indicates that over 70% of the internal surface of ammonia-synthesis catalyst is available for the reaction since the reaction is slow enough to permit the reactants to penetrate into the pores of the catalyst before they are depleted by the reaction.

Variations in gas velocity through the catalyst change the rate of reaction only when Step 1 above is a controlling factor. Since the evidence indicates that Steps 3 and 4 and Step 2 to some extent control the rate of this reaction, it is concluded that the rate of reaction is independent of gas velocity through the catalyst and a function of temperature, pressure, and gas composition only. When the reaction is carried out isothermally in a small volume of catalyst at two different space velocities, a higher per cent of ammonia is produced at the lower space velocity. This can be attributed to the longer residence time in the reactor at the lower space velocity. The rate of synthesis varies throughout the catalyst bed, owing to the increasing ammonia concentration. The difference between the ammonia formed at the low space velocity and that at the high, divided by the difference in residence time, is the rate of synthesis at the per cent of ammonia represented by the average of the exit concentrations at the two space velocities. This calculation can be made exact and the need for averaging the gas compositions avoided by measuring the slope of the curve of conversion of nitrogen and hydrogen to ammonia (based on measured exit ammonia concentrations) vs. the reciprocal of the space velocity. In Figures 7 and 8 the experimental data shown in Figures 4 and 5 have been plotted as conversion to ammonia vs. the reciprocal of the space velocity. The slopes of these curves when divided by 359, the standard mole volume, give the rate of formation of ammonia as pound moles per hour per cubic foot of catalyst. This method was also applied at other pressures and compositions, and the results are shown in Figures 9 through 13. The curves for 350° C. are omitted as having little interest in the design of a reactor for commercial use.



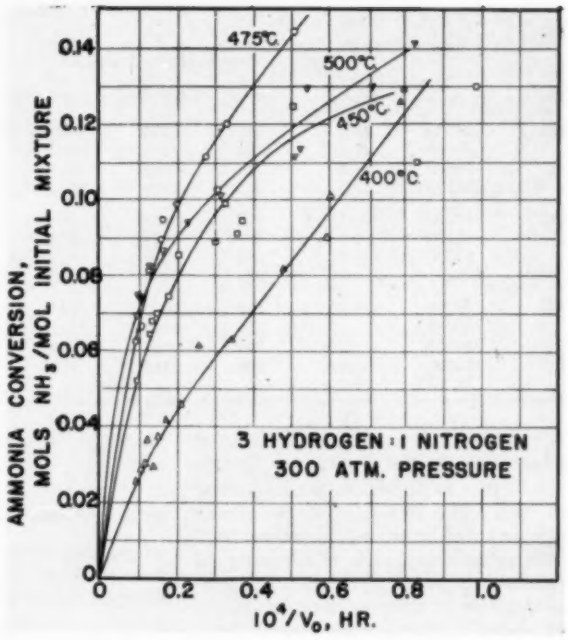
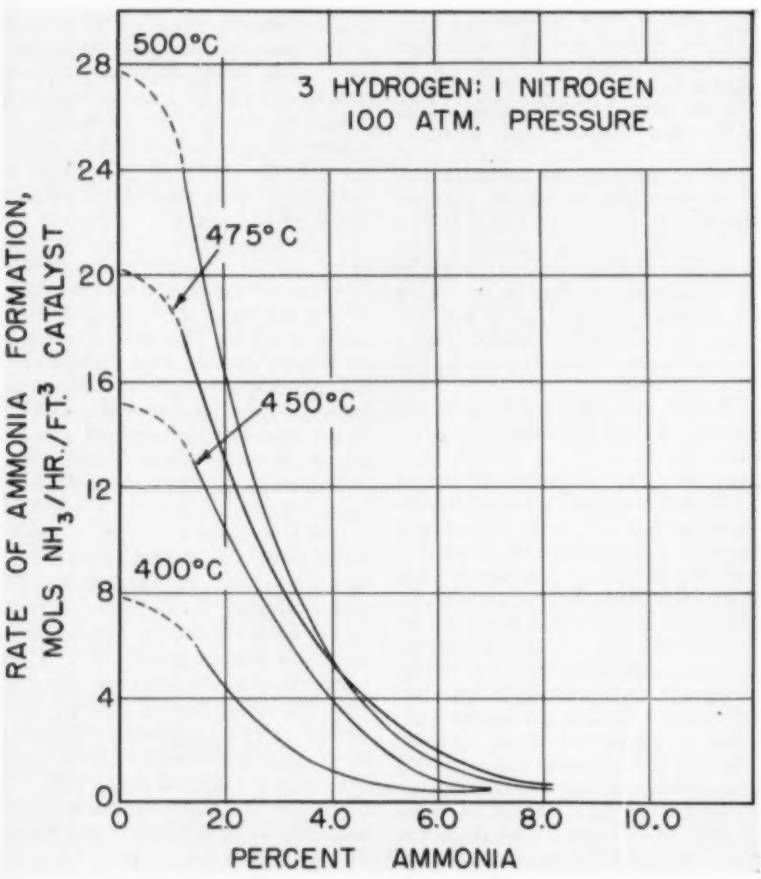


Fig. 7. Top left, Fractional conversion to ammonia vs. reciprocal of space velocity.
Fig. 8. Top right, Fractional conversion to ammonia vs. reciprocal of space velocity.
Fig. 9. Bottom, Rate of ammonia formation at 100 atm.



Design of an Ammonia Reactor

Much of the design of ammonia reactors is based on operating experience and semiempirical methods. The temperature distribution in the catalyst bed, while recognized as an important problem, has usually been treated in a qualitative manner or on a "cut-and-try" basis. A simple design method using data such as represented by Figures 9 through 13 and yielding the distribution of temperature and fractional conversion is desirable. The method proposed by Baron (*2*) is a major step in this direction. The instantaneous rates $R_1\rho_B$ of ammonia formation from Figure 10 have been employed to calculate the relations required by Baron's graphical method for the following case. A 2-in. I.D. tube is packed with catalyst, and a gas mixture which is initially 3:1 hydrogen to nitrogen is passed through it at 200 atm. total pressure at a rate of 10,000 lb./(hr.)(sq.ft.). The curves of $R_1\rho_B\lambda d_p\Delta Z'/C_pG$ vs. temperature at several values of per cent of conversion are shown in Figure 14. The curves of $R_1\rho_B M_{Avg} d_p\Delta Z' \times 10^3/Y'_1 G$ vs. per cent of conversion at several values of temperature are shown in Figure 15. Only preliminary graphical calculations were made for this one case, and these were not carried to the point where they provide a basis for firm conclusions. However, they indicated that near the inlet to the catalyst the reaction is fast enough so that radial temperature and concentration gradients are of less significance than the axial gradients along the tube. The reaction in the catalyst

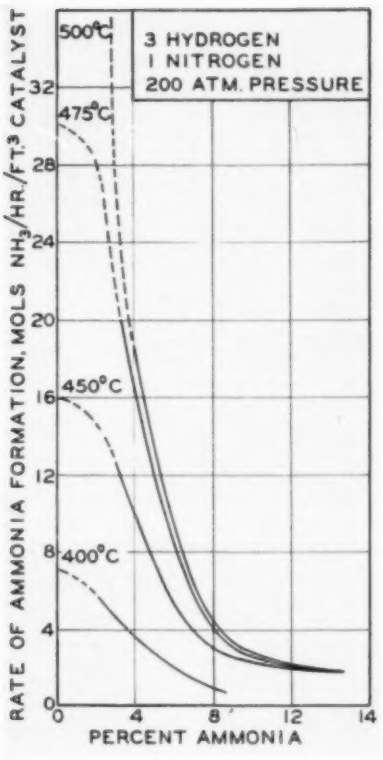
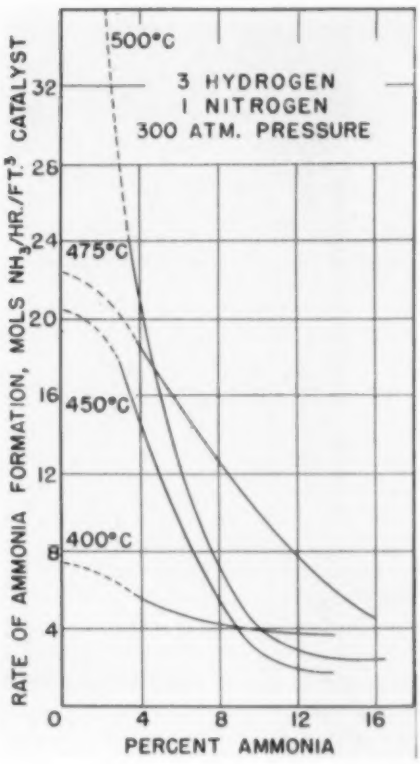


Fig. 10. Top left, Rate of ammonia formation at 200 atm.

Fig. 11. Top right, Rate of ammonia formation at 300 atm.

Fig. 12. Bottom, Rate of ammonia formation at 200 atm.



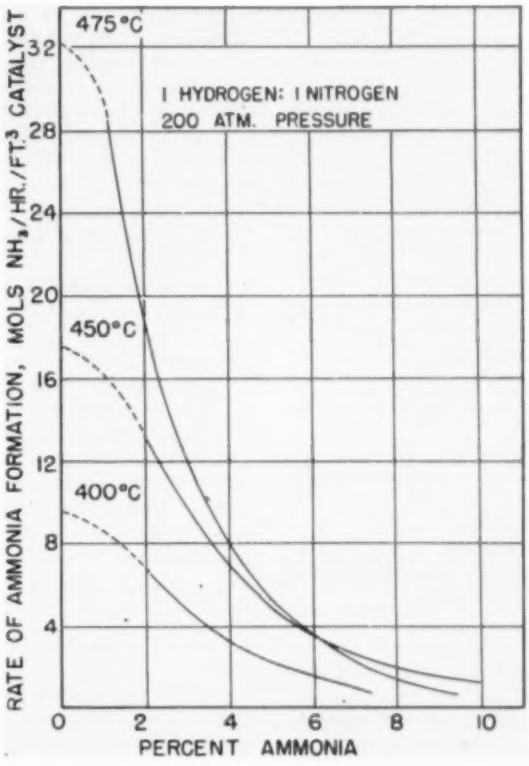
proceeds at an increasing rate and is brought under control as a result of the depressing effect of the increasing concentration of ammonia on the reaction rate as well as by the cooling effect of radial heat transfer and to a lesser extent by the effect of approaching reaction equilibrium. This is borne out by the axial temperature distribution in commercial reactors (*10*).

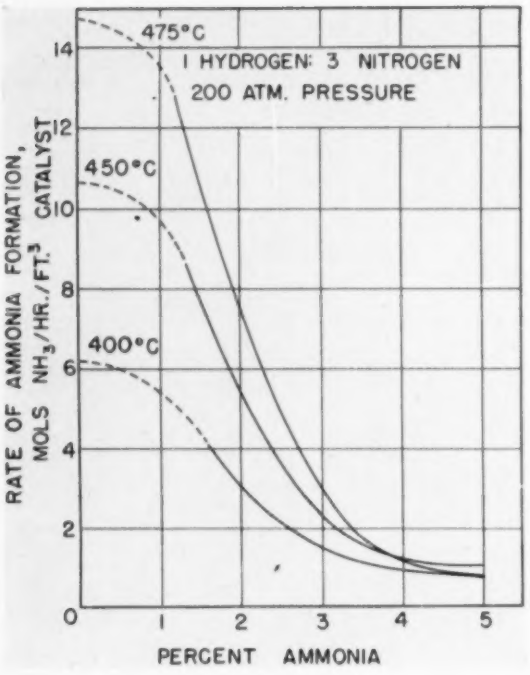
Acknowledgment

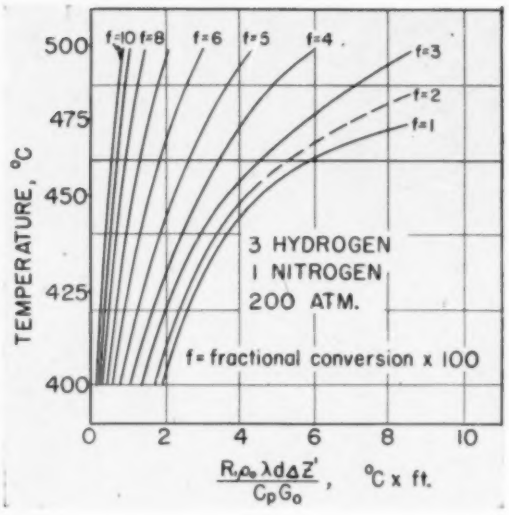
This investigation was carried out under a fellowship from the Pan American Refining Corporation. A. Mills contributed to the calculations in the section on Design of an Ammonia Reactor.

Notation

- a = activity
- $a^*_{N_2}$ = activity of nitrogen in equilibrium with adsorbed nitrogen on the catalyst surface
- b_o = constant
- C = compressibility factor = Pv/nRT
- C_s = compressibility factor at standard temperature and pressure
- C_p = heat capacity of gases B.t.u./(lb.)(° F.)
- d_p = equivalent diameter of catalyst particles, ft.
- G = mass velocity of gases, lb./(hr.)(sq.ft.)
- K = equilibrium constant defined by Equation (1)
- K_p = ratio of fugacity coefficients = $\frac{v^2_{NH_3}}{v^3_{H_2} v_{N_2}}$







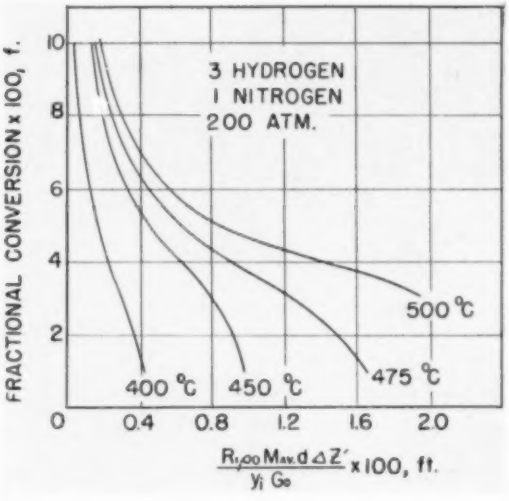


Fig. 13. Top left, Rate of ammonia formation at 200 atm.

Fig. 14. Top right, Temperature increment curves for use in Baron's reactor design method for conditions in text.

Fig. 15. Bottom right, Ammonia conversion increment curves for use in Baron's reactor design method.

k_a = constant
k_d = constant
k = constant
k' = reaction-rate constant
M_{Av_0} = average molecular weight of unreacted gas
n = mole fraction
N = moles of gas
N_e = moles of equivalent hydrogen-nitrogen mixture
P = total pressure
$P^*_{N_2}$ = equivalent partial pressure of adsorbed nitrogen
p = partial pressure
R = gas law constant
R_i = rate of ammonia formation, moles NH_3/(hr.)(lb. of catalyst)
t = time
U_o = volume of nitrogen-hydrogen mixture (at standard conditions) entering the catalyst bed/unit time
V_o = space velocity based on unreacted hydrogen-nitrogen mixture, $hr.^{-1}$
W = volume of catalyst
Y°_1 = mole fraction of nitrogen in unreacted gas
z = per cent of ammonia in gas
$\Delta Z'$ = longitudinal increments along the tube, ft.
α = ratio of mole fraction of hydrogen to mole fraction of hydrogen in 3:1 H_2:N_2 mixture
λ = heat of formation of NH_3, B.t.u./lb.mole
ρ_B = lb. of catalyst/cu.ft.
ν = fugacity coefficient = f/p
ϕ = fraction of voids in catalyst

Literature Cited

1. Adams, R. M., Ph.D. Thesis, University of Illinois (1950).

2. Baron, T., *Chem. Eng. Progress*, **48**, 118 (1952).

3. Emmett, P. H., and J. T. Kummer, *Ind. Eng. Chem.*, **35**, 677 (1943).

4. Gamson, B. W., G. Thodos, and O. A. Hougen, *Trans. Am. Inst. Chem. Engrs.*, **39**, 1-35 (1943).

5. Glasstone, S., "Thermodynamics for Chemists," p. 277, D. Van Nostrand Co., New York (1947).

6. Hougen, O. A., and K. M. Watson, *Ind. Eng. Chem.*, **35**, 529 (1943).

7. Hurt, D. M., *Ind. Eng. Chem.*, **35**, 522 (1943).

8. Larson, A. T., and R. S. Tour, *Chem. & Met. Eng.*, **26**, 647 (1922).

9. Sidorov, I. P., and V. D. Livshits, *J. Phys. Chem. (U.S.S.R.)*, **21**, 1177 (1947).

10. Slack, A. V., H. Y. Allgood, and H. E. Maune, paper presented at Cleveland meeting of A.I.Ch.E. (1952). In press.

11. Temkin, M. I., *J. Phys. Chem. (U.S.S.R.)*, **24**, 1312 (1950).

12. Temkin, M. I., and V. Pyzhev, *Acta Physicochim. (U.S.S.R.)*, **12**, 327 (1940).

13. Wheeler, A., paper presented at Symposium on Catalysis, A.C.S., Atlantic City (1952).

Presented at A.I.Ch.E. Minneapolis Meeting

Resistance and Compressibility of Filter Cakes

H. P. Grace

E. I. du Pont de Nemours and Company, Wilmington, Delaware

Part II: Under Conditions of Pressure Filtration

Methods for interpreting compression-permeability data in terms of actual pressure filtration conditions are applied to prediction of average specific cake-resistance values for ten materials. These predicted values are found to agree within ±10% with values determined from actual pressure filtration over a range of filtration pressure drop from 10 to 450 lb./sq.in. With several materials this agreement remained valid when suspensions were used that were characterized by different degrees of particle flocculation of the same material and that yielded cakes of widely different properties. The controlling role of particle flocculation with compressible cakes is further defined through the application of microscopic and light-transmission techniques for characterizing the degree of particle flocculation in the feed suspension and the correlation of degree of flocculation with values of average specific cake resistance for resulting filter cakes. Utility of compression-permeability method in sizing pressure or vacuum filters for compressible cakes is confirmed.

Part I of this paper described application of the compression-permeability method to the study of the properties of a wide range of compressible filter cakes. In this second part, means for interpreting these results in terms of actual pressure filtration are presented, and filtration results predicted from compression-permeability measurements are compared with actual filtration results for suspensions of the same materials. With several materials, such comparisons are made using suspensions characterized by different degrees of particle flocculation of the same material, and the practical importance of this variable in controlling filtration characteristics with compressible cakes is confirmed.

While the potential usefulness of the rate equation is great, its practical value is rather limited. By means of constant-pressure laboratory filtration data, the average specific cake resistance can be calculated for the pressure conditions of the test. To characterize a suspension fully, however, a series of constant-pressure filtration runs is necessary, so that the variation of average specific cake resistance and average cake porosity with filtration pressure may be determined. This involves considerable work and is seldom resorted to in plant problem work; the more usual procedure is to select one or two filtration pressures (not always near the expected operating filtration pressure), make laboratory filtration runs, and scale these runs up directly to plant conditions by utilizing the filtration-rate equation to indicate the effect of changes in external variables. Thus the average specific cake resistance is not established as a function of pressure, and usually the average specific cake resistance is not even calculated for the filtration pressure conditions considered. In the short run, this may be a time-saving device, but when other filtration pressures must be considered later, it results in additional work but not in real understanding of the cake behavior and properties. Also, this practice is largely responsible for the severe lack of information concerning the average specific cake resistance for various filter cakes; this precludes the making of intelligent high-spot estimates of the filtering characteristics of a material without tests.

An even more serious limitation of the filtration-rate equation results from the inability to control or predict the changes in average specific cake resistance which accompany changes in degree of suspension flocculation. Such changes in flocculation may result in tenfold changes in average specific cake resistance and account for many discrepancies between laboratory test results and plant performance or between plant performances from day to day.

The compression-permeability method provides a simple means of determining cake properties over a wide range of pressure stress by measurements on a single cake. Although the results of such measurements on a wide variety of material have shown that no simple relationship exists between α_p, ϵ_p, and p_s for compressible cakes, the average specific cake resistance under conditions of actual pressure filtration can still be simply calculated for any filtration pressure provided compression-permeability data are available.

During filtration of compressible cakes, the pressure stress causing physical compression of the cake results in general from (*a*) cumulative drag of filtrate flowing through cake pores, (*b*) component of existing gravitational field acting on cake solids in direction of filtrate flow through cake, and (*c*) kinetic energy changes in filtrate flowing through the cake. Since the over-all pressure stress increases in the direction of filtrate flow, the specific cake resistance α_p increases in the same direction. The average specific cake resistance α under such conditions can be obtained by writing the expression for α_p for a differential weight of cake solids and integrating between limits of compressive pressure at the faces of the cake. In Appendix *A* this has been done for the cases of pressure filtration on a flat filter surface oriented vertically, pressure filtration on a flat filter surface oriented in horizontal plane, and pressure filtration on inside or outside of cylindrical surface with axis vertical. For the simple case of pressure filtration on a flat vertical filtering surface, this results in the expression

Part I appeared in the June issue.

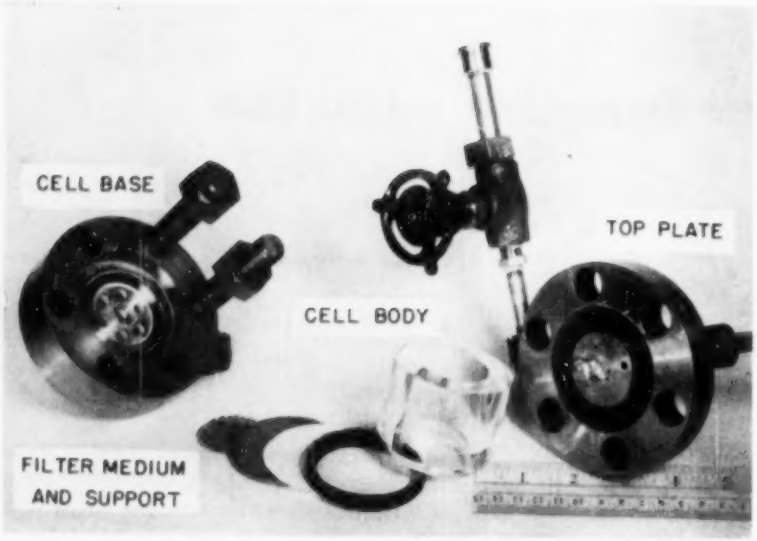


Fig. 1. High-pressure filtration cell (500 lb./sq.in.).

$$\int_0^{p_2 - p_1} \frac{dp_s}{a_p} = \frac{p_2 - p_1}{a} \quad (1)$$

A solution is then possible by numerical integration employing Simpson's rule and compression-permeability data for the $1/a_p$ vs. p_s function. An example calculation is presented in Appendix B as applied to removal of G-60 decolorizing carbon from a plant solution by pressure filtration.

While the value of a turns out to be independent of cake thickness L or weight of solids deposited W for the foregoing simple case, this is not true for the general case, where compressive pressure results from forces other than the cumulative drag resulting from filtrate flow. As indicated in Appendix A, however, a may be considered independent of L or W in filtration on a flat horizontal surface provided $\rho_f L$ is small compared to $p_2 - p_1$ and $(\rho_s - \rho_f)/\rho_s$ is small; this case then simplifies to the solution given in Equation (1) above.

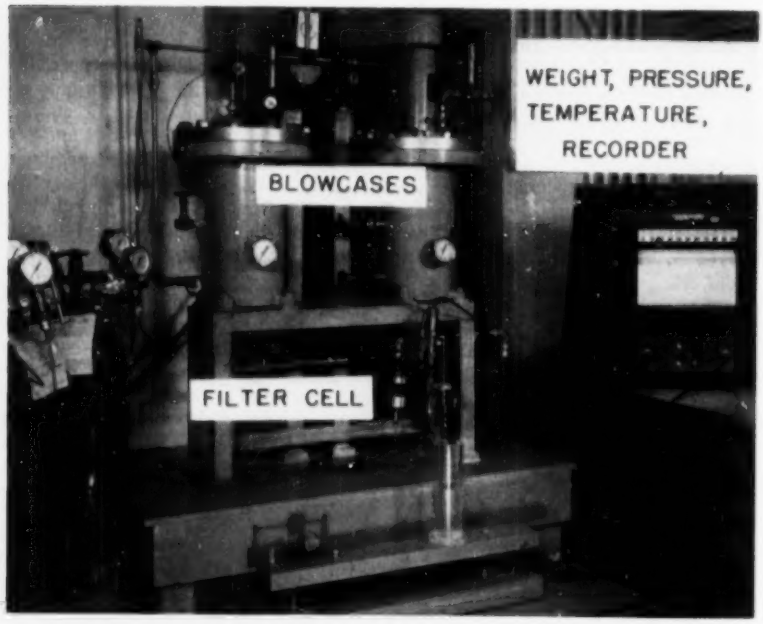


Fig. 2. Laboratory pressure-filtration apparatus.

Filtration Equipment and Procedure

In order to compare values of a predicted from compression-permeability data with a values during actual pressure filtration, flexible laboratory filtration apparatus was designed and built for operation at pressure drops up to 500 lb./sq.in.

Figure 1 shows a disassembled view of the pressure-filtration cell designed for use up to 500 lb./sq.in. Lucite acrylic resin and stainless cell bodies were made in various depths in order that cell volume above the filter cake might be kept to a minimum with various final cake thicknesses; this minimized settling effects in the filtration cell. Diameter of the filtration cell was 1.5 in., the same as the compression-permeability cell, while the Grade D porous stainless-steel base plate and machined drainage volume also duplicated the compression-permeability cell (described in Part I).

Figure 2 shows the over-all filtration apparatus, including the assembled filter cell, the specially designed blow cases used to furnish suspension and wash liquor under pressure, the specially designed strain-gauge balance for continuously measuring filtrate collected, and the strain-gauge pressure transmitter for measuring filtration pressure. This equipment set-up permitted constant-pressure-filtration runs to be made successfully at filtration pressures up to 500 lb./sq.in. Constant-pressure-drop filtrations at low values of Δp were also made using an 0.0842-sq.ft. Buchner funnel with Grade D porous stainless-steel drainage base. In both cases the filter base was covered with fresh Eaton & Dikeman No. 613 or 615 filter paper for each run, the type used corresponding to that used in the compression-permeability run.

The constant-pressure filtration data were treated in the usual manner by plotting $\Delta\theta/\Delta(V/A)$ vs. V/A, and values of a were calculated from slopes and of R_m from y intercepts of these curves, employing the filtration-rate equation in the form

$$\frac{\Delta\theta}{\Delta\left(\frac{V}{A}\right)} = \frac{\mu a w}{\Delta p g_c}\left(\frac{V}{A}\right) + \frac{\mu R_m}{\Delta p g_c} \quad (2)$$

The filtration runs were made on the same suspensions on which the previously reported compression-permeability runs were made. Whenever possible, they were made the same day as the compression-permeability run, both being made at room temperature in most cases. Average porosity ϵ of final filter cake as reported was calculated from physical dimensions of cell, cake thick-

TABLE 1.—CONSTANT PRESSURE-FILTRATION RUNS WITH VARIOUS MATERIALS

Suspension material and conditions	Temp., °C.	w, lb. dry solids cu.ft. filtrate	Filtration pressure drop, Δp, lb./sq.in.	Avg. cake porosity, ϵ, void fraction	Avg. sp. cake resistance α, ft./lb.	Filter medium resistance R_m, 1/ft.
Superlight $CaCO_3$,	27.3	3.05	10.3	0.778	10.6×10^{10}	6.7×10^{9}
Suspended in dist. water, pH = 9.8-10.0, single No. 613 paper, mild agitation (10^{-3} hp./1,000 gal.)	26.9	2.98	12.0	0.768	11.3×10^{10}	7.7×10^{9}
	31.5	2.98	15.3	0.773	11.5×10^{10}	10.8×10^{9}
	29.0	3.00	22.4	0.760	12.1×10^{10}	11.3×10^{9}
	26.9	3.06	26.3	0.758	11.7×10^{10}	9.2×10^{9}
	29.0	3.05	42.5	0.758	12.5×10^{10}	14.1×10^{9}
	26.9	3.02	62.8	0.749	15.1×10^{10}	16.4×10^{9}
	29.0	3.09	82.0	0.745	13.2×10^{10}	15.0×10^{9}
	26.3	3.03	134	0.721	17.0×10^{10}	19.1×10^{9}
	26.2	3.09	149	0.723	15.9×10^{10}	21.1×10^{9}
	25.9	2.99	232	0.717	20.3×10^{10}	26.3×10^{9}
	25.2	2.96	348	0.699	24.1×10^{10}	29.0×10^{9}
	25.0	2.97	444	0.693	24.3×10^{10}	30.6×10^{9}
Superlight $CaCO_3$,	25.1	2.99	22.5	0.709	22.6×10^{10}	16.5×10^{9}
Suspended in 0.01 M $Na_4P_2O_7$, pH = 10.6, single No. 613 paper, mild agitation (10^{-3} hp./1,000 gal.)	25.0	2.98	41.5	0.709	22.6×10^{10}	15.8×10^{9}
	25.0	2.97	83.5	0.704	23.8×10^{10}	17.9×10^{9}
	25.1	2.95	123	0.704	26.4×10^{10}	18.2×10^{9}
	25.3	2.95	224	0.700	26.4×10^{10}	36.7×10^{9}
	25.6	2.97	329	0.702	29.0×10^{10}	27.1×10^{9}
	25.5	2.96	450	0.697	29.0×10^{10}	30.8×10^{9}
R-110 TiO_2,	22.7	2.39	22.8	0.765	6.05×10^{11}	6.0×10^{10}
Suspended in dist. water, pH = 7.8, single No. 613 filter paper, mild agitation (10^{-3} hp./1,000 gal.)	23.2	2.33	43.8	0.729	7.68×10^{11}	6.75×10^{10}
	24.0	2.34	95.5	0.712	10.2×10^{11}	6.50×10^{10}
	24.7	2.36	172	0.658	11.9×10^{11}	8.02×10^{10}
	25.3	2.34	292	0.655	12.9×10^{11}	7.40×10^{10}
	25.9	2.38	442	0.638	14.0×10^{11}	Negative intercept
R-110 TiO_2,	29.3	2.74	24.7	0.723	10.4×10^{11}	7.90×10^{10}
Suspended in dist. water, pH = 7.8, single No. 613 paper, vigorous agitation (1.0 hp./1,000 gal.)	29.1	2.78	45.2	0.690	11.2×10^{11}	9.20×10^{10}
	28.8	2.80	98.1	0.693	14.1×10^{11}	11.25×10^{10}
	28.4	2.79	169	0.688	13.7×10^{11}	10.6×10^{10}
	28.5	2.75	302	0.663	16.1×10^{11}	7.7×10^{10}
	28.5	2.74	440	0.653	17.0×10^{11}	7.9×10^{10}
R-110 TiO_2,	24.9	3.10	22.7	0.707	26.5×10^{11}	5.0×10^{10}
Suspended in 0.01 N HCl, pH = 3.45, single No. 613 filter paper, mild agitation (10^{-3} hp./1,000 gal.)	25.5	3.20	43.6	0.712	27.2×10^{11}	Negative intercept
	26.1	3.07	97.4	0.670	30.5×10^{11}	8.3×10^{10}
	26.7	3.04	170	0.644	29.4×10^{11}	7.35×10^{10}
	27.2	3.05	292	0.624	30.1×10^{11}	8.52×10^{10}
	27.8	2.97	468	0.623	33.8×10^{11}	9.0×10^{10}
Talc C						
Suspended in 0.01 M $Al_2(SO_4)_3$, single No. 615 paper, mild agit.	26.0	3.31	7.32	0.805	1.8×10^{11}	1.0×10^{10}
Standard Super Cel						
Suspended in dist. water, pH = 7.50						
Single No. 613 paper, mild agitation	26.0	3.67	7.40	0.860	6.16×10^{10}	1.16×10^{10}
	25.8	3.58	7.40	0.860	6.0×10^{10}	0.88×10^{10}
Double No. 613 paper, mild agitation	26.1	3.65	7.40	0.855	6.23×10^{10}	1.60×10^{10}
Suspended in 1 N NaCl						
Single No. 613 paper, mild agitation	25.0	3.77	7.40	0.870	2.22×10^{10}	0.71×10^{10}
G-60 Darco						
Suspended in dist. water pH = 7.50						
Single No. 615 paper, mild agitation	25.8	3.66	7.40	0.850	4.10×10^{10}	0.51×10^{10}
Single No. 613 paper, mild agitation	25.9	3.66	7.40	0.850	4.41×10^{10}	0.76×10^{10}
Suspended in 1 N NaCl						
Single No. 613 paper, mild agit.	25.0	3.77	7.40	0.860	4.17×10^{10}	0.71×10^{10}
Conditioned 5040-F nylon satin, mild agitation	23.3	3.56	3.67	0.853	3.39×10^{10}	0.45×10^{10}
	23.3	3.59	7.36	0.848	4.01×10^{10}	0.54×10^{10}
	23.2	3.56	11.18	0.839	4.68×10^{10}	0.55×10^{10}
Precipitated ZnS						
Precipitated hot, suspended in mother liquor, pH = 9.15, single No. 615 paper, mild agitation	51.5	30.6	3.69	0.863	1.88×10^{11}	2.4×10^{10}
	56.5	30.9	7.74	0.859	2.64×10^{11}	1.8×10^{10}
	50.5	30.5	11.42	0.854	3.10×10^{11}	1.7×10^{10}
Precipitated cold, suspended in mother liquor, pH = 9.20, single No. 615 paper, mild agitation	55.3	24.1	3.63	0.870	1.14×10^{12}	1.0×10^{11}
	55.7	23.9	7.32	0.867	1.84×10^{12}	1.5×10^{11}
	57.7	24.1	11.46	0.864	2.53×10^{12}	1.5×10^{11}

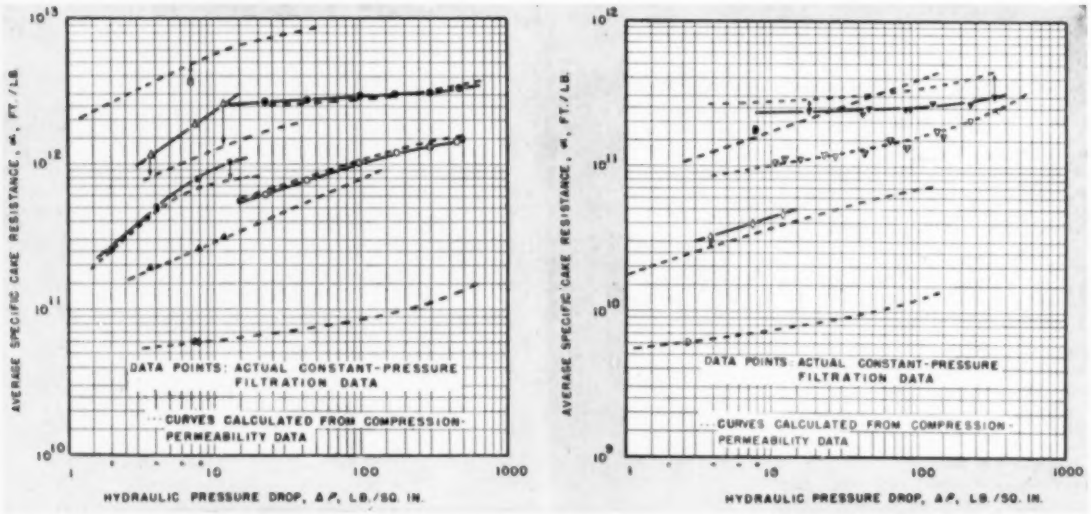
TABLE 1.—(Continued)

Suspension material and conditions	Temp., °C.	w, lb. dry solids cu.ft. filtrate	Filtration pressure drop, Δp, lb./sq.in.	Avg. cake porosity, ϵ, void fraction	Avg. sp. cake resistance α, ft./lb.	Filter medium resistance R_m, 1/ft.
Fine Silica						
Suspended in mother liquor, single No. 613 paper, mild agit.	27.1	4.34	1.88	0.978	2.52×10^{11}	2.7×10^{10}
	24.3	3.70	4.10	0.978	4.95×10^{11}	4.8×10^{10}
	24.1	3.43	7.57	0.977	8.09×10^{11}	3.5×10^{10}
	27.2	3.95	12.92	0.976	10.5×10^{11}	8.2×10^{10}
Linde Type A Alumina						
Suspended in 0.01 M $Al_2(SO_4)_3$, single No. 613 paper, mild agit.	25.3	3.76	2.61	0.863	6.25×10^{9}	5.1×10^{9}
Eimer & Amend Kaolin						
Suspended in 0.01 M $Al_2(SO_4)_3$, mild agitation, No. 615 paper	32.0	3.14	7.35	.....	6.9×10^{11}	7.0×10^{9}
Suspended in 0.01 M $Na_4P_2O_7$, mild agitation, No. 615 paper	32.1	3.04	7.40	.....	62.2×10^{11}	5.3×10^{10}
Iron Blue Pigment						
Suspended in mother liquor, single No. 613 paper, mild agit.	29.1	8.47	6.86	0.900	3.53×10^{12}	1.8×10^{10}

ness, and weight of dry solids in cake, this method being found much more reproducible and accurate than values calculated from wet and dry weights of cake. The reported value of w was measured directly in each run, based on final filtrate volume with saturated cake and weight of dry solids in cake. This measured value generally agreed within $\pm 10\%$ with a value calculated from feed-suspension concentration and cake porosity. Filtrate viscosity at filtration temperature was measured with a Hoeppler falling-ball viscometer. Final V/A values for the filtration runs varied from 0.7 to 2.2 cu.ft./sq.ft. while final wV/A values varied from 2 to 7 lb. dry solids/sq.ft. for most runs. Negligible initial bleed was encountered on all runs, even at pressure drops as high as 450 lb./sq.in. Calculations based on flow rate over first 5 sec. of filtration also showed that with material filtered at 450 lb./sq.in., the N_{Re} based on cake did not exceed 1.0 even during this initial interval of filtration. Table 1 summarizes the filtration results obtained from sixty-three constant-pressure filtration runs on various suspensions of ten of the materials previously studied by the compression-permeability technique.

Actual and Predicted Filtration Results

Equation (1) provides a means for predicting from compression-permeability data the average specific cake resistance α of filter cakes formed in pressure filtration. Figure 3 shows the generally good agreement between such predicted values and actual pressure filtration values for a number of the materials studied. For the flocculated and the dispersed titanium dioxide suspen-


AVERAGE SPECIFIC CAKE RESISTANCE, α, FT./LB.
DATA POINTS: ACTUAL CONSTANT-PRESSURE FILTRATION DATA
CURVES CALCULATED FROM COMPRESSION-PERMEABILITY DATA
HYDRAULIC PRESSURE DROP, ΔP, LB./SQ. IN.
AVERAGE SPECIFIC CAKE RESISTANCE, α, FT./LB.
DATA POINTS ACTUAL CONSTANT-PRESSURE FILTRATION DATA
CURVES CALCULATED FROM COMPRESSION-PERMEABILITY DATA
HYDRAULIC PRESSURE DROP, ΔP, LB./SQ. IN.

- ○ R-110 TiO_2, 50 g./l. distilled water
- ● R-110 TiO_2, 50 g./l. 0.01 N HCl
- △ Zn S, Type B suspensions, 300 g./l.
- ▲ Zn S, Type A suspension, 300 g./l.
- □ Iron-blue pigment, plant filter feed
- ■ Fine silica
- ◇ G-60 Darco activated carbon, 50 g./l. 1 N NaCl
- ◆ Standard Super-Cel filter aid, 50 g./l. distilled water
- ◗ Linde Type A alumina, 50 g./l. of 0.01 M $Al_2(SO_4)_3$
- ◗ Talc C, 50 g./l. of 0.01 M $Al_2(SO_4)_3$
- ▽ Superlight $CaCO_3$, 50 g./l. of distilled water
- ▼ Superlight $CaCO_3$, 50 g./l. of 0.01 M $Na_4P_2O_7$

Fig. 3. Comparison of actual and predicted filtration data.

sions, the agreement was very good over the entire pressure-drop range from 20 to 500 lb./sq.in. For the zinc sulfide suspensions, the agreement was very good for type *A* suspension but rather poor for type *B*. Aging may have changed suspension properties in this case. A spot check with iron blue pigment showed fair agreement, while data for fine silica showed good agreement over the 2- to 15-lb./sq.in. range. Spot filtration data on Talc C, Linde alumina, and Standard Super-Cel show good agreement with the predicted curves. Filtration data on *G*-60 Darco fell 10% above the predicted curve. Filtration data on the suspensions of calcium carbonate show very good agreement over a wide pressure-drop range with the flocculated suspension, but filtration results fell 20% below predicted values for the dispersed suspension.

Considering the accuracy of both the pressure-filtration and the compression-permeability data, these results show that prediction of average specific cake-resistance values from compression-permeability data will be accurate to ±10% in most cases, provided suspension properties do not change. Since the compression-permeability method covers a wide pressure range and yields a large amount of useful data for a single run, it is a valuable tool in the selection and sizing of filters as well as in the study of cake properties.

Integration of Equation (1), by means of compression-permeability data, results in predicted curves of α vs. Δp for pressure filtration which in many cases cannot be represented by the simple expression $\alpha = \alpha_o + \alpha'(\Delta p_c)^s$ over a wide range of pressure drop, this expression failing above 50 to 100 lb./sq.in. Thus, the predicted curves of log α vs. log Δp often show curvature (Fig. 3) above this pressure range, indicating that the so-called "compressibility factor" s of the foregoing expression is constant only over the low-pressure region. This is borne out by the actual filtration data (Fig. 3) for a number of the materials, which show some form of deviation at elevated pressures. In some cases the integration of the α_p-vs.-p_s curve to yield α vs. Δp resulted in a constant exponential relationship with constant s value. With the highly flocculated materials of very small particles—such as fine silica, titanium dioxide, and iron blue—the compressibility factor s decreased at high pressure drops, resulting in a flattening out of the α-vs.-Δp curve. With other fine materials, such as *G*-60 Darco and precipitated zinc sulfide, a constant compressibility factor resulted, while with some materials of very irregular shape, such as talc, Standard Super-Cel, and calcium carbonate, the value of compressibility factor s increased at elevated pressure drops.

In any case the predicted and actual curves of Figure 3 make it apparent that extrapolation of values of α at elevated pressures on the basis of results at low pressures, by use of the simple relationship $\alpha = \alpha_o + \alpha'(\Delta p_c)^s$, is not adequate or reliable in many cases and may result in either too large or too small values, depending on the particular material. For this reason the compression-permeability method, which covers a wide pressure range in a single run, is of particular value, since the necessity for extrapolation of low-pressure measurements is eliminated.

In general, values of R_m reported in Table 1 for the filtration runs increase with increasing filtration pressure drop with a given material, but considerable scatter occurs. This scatter probably results from the difficulty in accurately determining the small numerical value of the intercept used in the calculation of these values. In any case the empirical observation can be made that for the majority of the runs with all materials, R_m was numerically equal to 0.05 to 0.1a for that particular run, with a considerable number of runs resulting in $R_m = 0.1a$. This means that for these cases, R_m was equal to the resistance of 0.1 lb. solids/sq.ft. of filter surface. Depending on the cake porosity, this represents the resistance of a cake 0.01 to 0.06 in. in thickness. This approximate value, $R_m \simeq 0.1a$, has been observed to hold well for various media provided the medium is of a tightness generally suited to the class of materials being filtered. Thus the use of $R_m \simeq 0.1a$ as a first approximation appears justified and is probably sufficiently accurate for most practical filtration calculation unless very thin cakes are to be handled.

Measurement of Suspension Flocculation

Results of the compression-permeability measurements and the filtration runs have shown that small changes in chemical composition of the suspending liquid have a large influence on the resistance and compressibility of the resulting cake with a given material. Conclusive evidence that this variation in cake properties results from changes in degree or type of particle flocculation in the feed suspension has been obtained by comparing photomicrographs of the suspension, the light-transmission characteristics of the suspension, the sedimentation characteristics of the suspension, and the filtration characteristics of the suspension for a wide variety of electrolytes and electrolyte contents in the suspending liquid with a given suspended material.

Light-transmission measurements have been investigated by Rose and Lloyd (*5*), Skinner and Boas-Traube (*6*), and Skinner and Withers (*7*) as a means of measuring the specific surface of particles in suspension. Such measurements have also been used by Hubley, et al. (*2*), Kopelman and Gregg (*3*), Tuller and Fulmer (*9*), and Troelstra and Kruyt (*8*) to study rate and degree of particle flocculation in suspensions. The basis for this method of measurement is the Lambert-Beer law,

$$S_p = \frac{i}{cb} \ln \frac{I_o}{I} \qquad (3)$$

Since flocculation is normally three dimensional, the shadow-projected area S_p will vary with changes in suspension flocculation. If cell thickness b and suspension concentration c are held constant and the opacity factor i remains constant, then changes in the extinction coefficient $\ln I_o/I$ will represent only changes in degree of particle flocculation. The Lambert-Beer law has been shown to hold for particles down to 2μ or smaller with white light. It is based on random particle motion in the suspending fluid and has been shown to express correctly the effect of cell thickness and suspension concentration, provided the apparatus is constructed so as to prevent forward scattered light from reaching the phototube (*5* and *6*). When the relationship for flocculation measurement is used, it is assumed that the effective particle opacity i is independent of effective particle size and a function only of the relative refractive indexes of the liquid and solid over the range of particle size involved. Although recent work by Rose and French (*4*) has shown that this assumption is not true, the resulting approximation is sufficiently good for the semiquantitative measurement of degree of particle flocculation.

The equipment used in making the light-transmission measurements was basically the same as that used by others (*6* and *7*). A continuously rotating sample cell was developed to prevent settling of highly flocculated suspensions during measurement. The optical arrangement and thin cell, $b = 0.10$ mm., resulted in a minimum of forward scattered light reaching the phototube. Aqueous solutions of various electrolytes were prepared in the range of concentration from 0.00001 to 1.0 molar, and titanium dioxide was added to make a concentration of 50 g./liter of solution. The suspensions were mechanically agitated and aged 24 hr. Photomicrographs were then taken and measurements were made of light-extinction coefficient, average specific cake resistance, and comparative sedimentation

rate, using the original suspension without dilution. Values of α for the various suspensions were determined at a pressure drop of 4.76 lb./sq.in. by use of an 0.0842-sq.ft. Buchner funnel with Grade *D* porous stainless-steel base and 3-g. precoat of Standard Super-Cel. Values of α and R_m so determined and values of ln I_o/I for various titanium dioxide suspension are given in Table 2.

Effect of Suspension Flocculation on Filtration Resistance

Figure 4 shows a correlation between α and the degree of particle flocculation in titanium dioxide suspensions as characterized by the measured-light-extinction coefficient. This correlation shows that different forms of flocculation can result in identical light-extinction coefficients on suspensions yielding cakes of widely different resistance. This appears to result from a difference between the mechanism of dispersion and that of reflocculation in the suspension. Thus, the correlation of α with ln I_o/I exhibits a hysteresis loop as the electrolyte concentration is increased to and beyond the concentration for optimum dispersion.

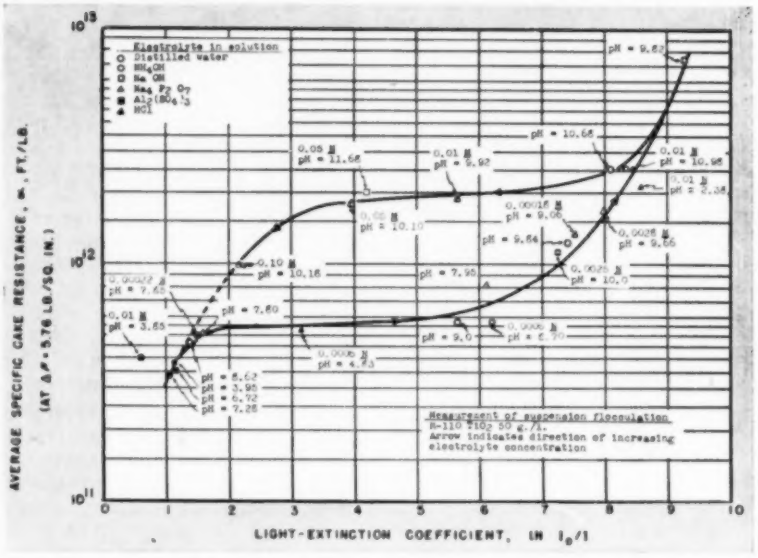


Fig. 4. Specific cake resistance vs. light-extinction coefficient R-110 TiO_2 suspensions.

TABLE 2.—FILTRATION AND LIGHT-TRANSMISSION MEASUREMENTS ON TITANIUM DIOXIDE SUSPENSIONS

(Grade *D* porous stainless-steel Buchner with Standard Super-Cel precoat of 0.079 lb./sq.ft.)

Suspension material and conditions	Temp., °C.	w, lb. dry solids cu.ft. filtrate	Filtration pressure drop p, lb./sq.in.	Av. sp. cake resistance α, ft./lb.	Filter medium resistance R_m, 1/ft.	Light extinction coeff.,* ln I_o/I
R-110 TiO_2, 50 g./liter, suspended in						
Distilled water, pH = 7.28	30.5	3.25	4.72	3.43×10^{11}	4.9×10^{10}	1.08
Very dilute $Al_2(SO_4)_3$, pH = 6.72	26.0	3.22	4.76	3.59×10^{11}	4.6×10^{10}	1.12
0.001 M $Al_2(SO_4)_3$ pH = 3.95	26.0	3.24	4.76	3.86×10^{11}	5.3×10^{10}	1.16
0.01 M $Al_2(SO_4)_3$ pH = 3.75	27.0	3.22	4.76	4.04×10^{11}	5.7×10^{10}	0.59
Very dilute NH_4OH, pH = 8.62	26.0	3.24	4.76	4.60×10^{11}	6.1×10^{10}	1.34
Dilute NH_4OH, pH = 9.00	26.0	3.26	4.76	5.75×10^{11}	3.7×10^{10}	5.64
Dilute NH_4OH, pH = 9.84	27.3	3.21	4.76	1.24×10^{12}	2.8×10^{10}	7.41
Stronger NH_4OH, pH = 10.68	26.5	3.23	4.76	2.53×10^{12}	2.1×10^{10}	8.08
0.00022 *N* NaOH, pH = 7.85	24.7	3.28	4.76	5.06×10^{11}	4.3×10^{10}	1.53
0.0006 *N* NaOH, pH = 8.70	24.7	3.25	4.76	5.82×10^{11}	4.3×10^{10}	6.18
0.0025 *N* NaOH, pH = 10.00	22.2	3.22	4.76	1.13×10^{12}	2.0×10^{10}	7.25
0.01 *N* NaOH, pH = 10.98	27.7	3.26	4.76	2.54×10^{12}	3.1×10^{10}	8.31
0.05 *N* NaOH, pH = 11.68	24.9	3.21	4.76	2.02×10^{12}	1.7×10^{10}	4.09
Dilute $Na_4P_2O_7$, pH = 7.80	26.4	3.28	4.76	5.27×10^{11}	4.5×10^{10}	1.60
Dilute $Na_4P_2O_7$, pH = 7.95	26.2	3.25	4.76	8.23×10^{11}	2.4×10^{10}	5.11
0.00018 M $Na_4P_2O_7$, pH = 9.06	25.9	3.23	4.76	1.37×10^{12}	1.9×10^{10}	7.50
0.00285 M $Na_4P_2O_7$, pH = 9.66	27.8	3.21	4.76	1.68×10^{12}	3.0×10^{10}	7.98
0.01 M $Na_4P_2O_7$, pH = 9.92	26.0	3.25	4.76	1.90×10^{12}	3.0×10^{10}	6.63
$Na_4P_2O_7$, pH = 10.10	24.6	3.21	4.76	1.81×10^{12}	3.4×10^{10}	3.97
0.01 M $Na_4P_2O_7$, pH = 10.18	26.8	3.26	4.76	1.00×10^{12}	2.0×10^{10}	2.17
0.0006 *N* HCl, pH = 4.83	24.3	3.30	4.76	5.36×10^{11}	4.0×10^{10}	3.15
0.01 *N*, HCl, pH = 2.38	28.5	3.21	4.76	2.15×10^{12}	3.1×10^{10}	8.54
0.011 *N* NaOH, pH = 11.30	22.5	3.24	4.76	3.12×10^{12}	1.25×10^{10}	9.12
Same suspension treated with IR-120 ion exchange resin to pH = 9.82	21.9	3.20	4.76	7.52×10^{12}	1.9×10^{10}	9.23
Same suspension treated with IR-120 ion exchange resin to pH = 8.90	26.9	3.25	4.76	1.57×10^{12}	3.5×10^{10}	9.00
Same suspension treated with IR-120 ion exchange resin to pH = 7.0	23.8	3.24	4.76	9.81×10^{11}	1.8×10^{10}	6.02
Same suspension neutralized with H_2SO_4 to pH = 8.70	26.4	3.26	4.76	1.13×10^{12}	1.0×10^{10}	3.64
Same suspension neutralized with H_2SO_4 to pH = 7.00	23.4	3.28	4.76	9.12×10^{11}	1.2×10^{10}	0.98
0.05 *N* NaOH, pH = 11.85	23.0	3.25	4.76	1.80×10^{12}	1.8×10^{10}	4.24
Same suspension treated with IR-120 ion exchange resin to pH = 11.20	24.6	3.21	4.76	1.66×10^{12}	9.2×10^{9}	9.03
Same suspension neutralized with H_2SO_4 to pH = 11.22	24.8	3.29	4.76	8.67×10^{11}	2.1×10^{10}	3.30

* For suspension as filtered, $c = 0.0117$ cu.cm./cu.cm., $b = 0.100$ mm.

This is well shown for *R*-110 titanium dioxide by the upper plot of Figure 6. This curve shows that as electrolyte concentration increases to the point of maximum dispersion, both a and $\ln I_o/I$ increase; however, the decreasing curve beyond the point of optimum dispersion follows a path corresponding to a much higher cake resistance than that of the rising curve for the same light extinction. This hysteresis is probably related to the multiple forces of flocculation, as described by Hauser (*1*), which result not only from electrokinetic effects, but also from solvation effects and effects related to dipole formation in the surface layer of the solid particles. In any case, an over-all deflocculation or dispersion mechanism corresponding to gradual breaking away from the floc of individual discrete particles until finally all flocs are broken down would result in a combination of relatively large flocs and many discrete particles in suspension over a large portion of the rising curve. A reflocculation mechanism corresponding to initial flocculation of all discrete particles into two or three particle flocs followed by progressive combination of these very small flocs to form larger flocs would result in nearly all particles being combined in small but uniformly sized flocs over a large portion of the falling curve of the loop. These mechanisms appear to agree with the manner in which cake resistance increases and decreases as electrolyte concentration increases. These mechanisms also appear to agree with the settling characteristics of the various suspensions. Thus the partially reflocculated suspensions cleared much more rapidly and settled to a smaller volume than the partially deflocculated suspension of the same light-extinction coefficient, but the latter showed a much lower filtration resistance than the former.

Although the principle of controlled particle flocculation as a means of improving filterability is generally recognized, failure to recognize the delicate and fugitive nature of this variable often results in serious scale-up difficulties. Thus very small changes in the chemical nature of the suspending liquid have been shown quantitatively to result in very large changes in filterability. The filtration results with flocculated titanium dioxide suspension (Table 1) also emphasize the large effect that mechanical treatment can have on filterability where particle flocculation is a factor. Thus increasing the agitation intensity in the filter feed vessel from 0.001 hp./1,000 gal. to 1.0 hp./1,000 gal. resulted in a substantial increase in a at moderate filtration pressures but resulted in formation of a less compressible cake. This effect is not unusual, but is very often overlooked when laboratory filtration results are sized to the plant, where mechanical treatment may vary widely.

Summary

Means have been developed for using compression-permeability data to predict the average specific cake resistance to be expected under conditions of pressure filtration. Such predicted values of a have been found to agree within ±10% with values of a determined by actual pressure filtrations. This agreement has been obtained with a wide variety of materials and over a wide range of filtration pressure drop. Since the compression-permeability method requires measurements on only a single cake in order completely to characterize the filtration properties of a suspension, this method is more rapid and flexible than the constant-pressure or constant-rate filtration methods normally employed and is well adapted to use with materials forming compressible cakes.

The major effect of particle flocculation in controlling filter-cake resistance and compressibility has been demonstrated in a quantitative manner with several materials. Degree of particle flocculation as characterized by photomicrographs and light-transmission measurements on the feed suspension has been shown to correlate qualitatively with measurements of filter-cake resistance. These correlations indicate that the mechanisms of deflocculation and reflocculation in a suspension, which accompany continued increase in the concentration of certain electrolytes, are distinctly different and result in filter cakes of widely different characteristics for varying forms of partially flocculated suspensions. In this connection comparative rates of sedimentation for suspensions of a material are not necessarily indicative of comparative filtration rates to be expected.

Notation

A = cross-sectional area of cake perpendicular to direction of flow, area of active filter medium, sq.ft.

A_{lm} = log mean cross-sectional area of cake perpendicular to direction of flow, sq.ft.

A_m = arithmetic average cross-sectional area of cake perpendicular to direction of flow, sq.ft.

b = thickness (length of light path) of sample cell in photometric measurements, cm.

c = volumetric concentration of solids in suspension, cu.cm. solids/cu.cm.

d = differential operator

f = function

g = acceleration in gravitational field, ft./(sec.)^2

g_c = conversion factor in Newton's law of motion, 32.2 (lb.)(ft.)/(lb. force)(sec.)^2

h = length of cylindrical filtering surface, ft.

i = extinction or opacity factor in Lambert-Beer law, dimensionless

I = relative light intensity at phototube with suspension in sample cell

I_o = relative light intensity at phototube with suspending liquid in sample cell

L = cake thickness in direction of flow, ft.

$N_{Re} = \rho_l v/\mu S_v(1-\epsilon)$

p = hydraulic pressure at a point in cake, lb./sq.ft. of cake cross section

p_o = hydraulic pressure on discharge side of filter medium, lb./sq.ft.

p_1 = hydraulic pressure on cake side of filter medium, lb./sq.ft.

p_2 = hydraulic pressure at exposed surface of filter cake, lb./sq.ft.

p_g = hydraulic-pressure component developed by liquid flowing through cake, through action of gravitation field, lb./sq.ft.

p_s = total mechanical compressive pressure developed in cake structure in direction of flow, lb./sq.ft. of cake cross section

p_v = hydraulic-pressure component developed by liquid flowing through cake, through a change in kinetic energy of liquid as flow through cake occurs, lb./sq.ft.

p_w = mechanical compressive pressure developed in cake structure, in direction of flow, resulting only from weight of cake solids acted upon by gravitational field, lb./sq.ft.

Δp = total hydraulic-pressure drop across cake and filter medium in pressure filtration, lb./sq.ft.

Δp_c = hydraulic pressure drop across cake in pressure filtration, lb./sq.ft.

Δp_m = hydraulic pressure drop across filter medium in pressure filtration, lb./sq.ft.

Q = instantaneous rate of filtrate flow through cake, cu.ft./sec.

r = radius to any point within cake when filtering on a cylindrical surface, ft.

r_o = radius to cake side of the filter-medium surface when filtering on a cylindrical surface, ft.

r_2 = radius to exposed cake surface when filtering on a cylindrical surface, ft.

R = over-all resistance in pressure filtration, 1/ft.

R_m = filter-medium resistance, 1/ft.

s = compressibility factor of filter cake, $a = a_o + a'(p_2 - p_1)^s$, dimensionless

S_v = particle specific surface, sq.ft./cu.ft. solid *

S_p = particle shadow-projected area, sq. cm./cu.cm. solid.

v = superficial flow velocity through cake, ft./sec.

* Multiply S_v in c.g.s. units by 30.5 to get S_v in f.p.s. units.

V = volume of filtrate collected at time, θ, cu.ft.

W = total weight of solid particles in cake, lb.

w = weight of solid particles deposited in cake per unit volume of filtrate, lb./cu.ft.

α = average specific cake resistance of actual filter cake (weight basis), ft./lb.

α_p = specific cake resistance at any point in cake, ft./lb.

α_o, α' = constants of equation, $\alpha = \alpha_o + \alpha'(p_2 - p_1)^s$

ϵ = average cake porosity or void fraction, dimensionless

ϵ_p = porosity or void fraction at any point in cake, dimensionless

θ = time of filtration, sec.

ρ_f = density of suspending liquid or filtrate, lb./cu.ft.

ρ_s = density of solid particles, lb./cu.ft.

μ = filtrate viscosity, lb./ft.sec.

Consistent units, suitable for direct use in all equations of this paper, are given in this nomenclature. More readily grasped units have been used in plotting several curves shown in the figures.

Literature Cited

1. Hauser, E. A., *J. Phys. & Colloid Chem.*, **55**, 605 (1951).
2. Hubley, C. E., A. A. Robertson, and S. G. Mason, *Can. J. Research*, **28**B, 770 (1950).
3. Kopelman, B., and C. C. Gregg, *J. Phys. & Colloid Chem.*, **55**, 557 (1951).
4. Rose, H. E., and C. C. J. French, *J. Soc. Chem. Ind. (London)*, **67**, 283 (1948).
5. Rose, H. E., and H. B. Lloyd, *J. Soc. Chem. Ind. (London)*, **65**, 52 (1946).
6. Skinner, D. G., and S. Boas-Traube, *Trans. Inst. Chem. Engrs. (London), Supplement*, **25**, 57 (1947).
7. Skinner, D. G., and A. G. Withers, *Trans. Inst. Mining Engrs. (London)*, **105**, 684 (1946).
8. Troelstra, S. A., and J. R. Kruyt, *Kolloid-Beihefte*, **54**, 225 (1943).
9. Tuller, E. F., and E. I. Fulmer, *J. Phys. & Colloid Chem.*, **52**, 787 (1948).

Appendix A.—Interpretation of Compression-Permeability Data in Terms of Pressure-Filtration Conditions

The filtration-rate equation as derived for a flat filtration surface of constant area (constant cake-cross-sectional area as well as constant filter-surface area) can be written as

$$Q = \frac{Ag_c\Delta p}{\mu\left(\frac{\alpha W}{A} + R_m\right)} \quad (1)$$

For the case of a constant-pressure filtration, the over-all-pressure drop can be written as

$$\Delta p = \Delta p_{cake} + \Delta p_{cloth} = \text{constant}$$

or

$$p_2 - p_o = (p_2 - p_1) + (p_1 - p_o) \quad (2)$$

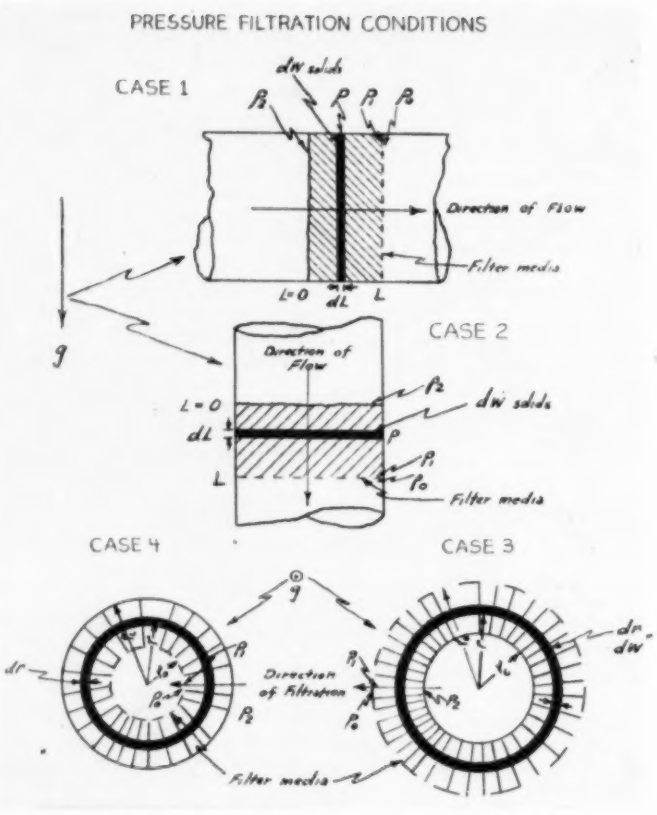


Fig. A1. Further interpretation of compression-permeability data.

where p_o = discharge pressure and p_2 = hydraulic pressure at surface of cake.

Also, rearranging (1) for constant pressure filtration gives

$$\Delta p = \frac{Q\mu\alpha W}{g_c A^2} + \frac{Q\mu R_m}{Ag_c} \quad (3)$$

where at any instant in filtration cycle

$$p_2 - p_1 = \frac{Q\mu\alpha W}{A^2 g_c} = \Delta p_c \quad (4)$$

$$p_1 - p_o = \frac{Q\mu R_m}{Ag_c} = \Delta p_m \quad (5)$$

and

$$\frac{p_1 - p_o}{p_2 - p_1} = \frac{AR_m}{\alpha W} \quad (5a)$$

For any instant in constant-pressure-filtration cycle, Equation (4) may be obtained by writing Bernoulli's energy balance across entire cake to obtain an over-all equation involving α. Equation (4) as written above is the balance for the case of constant filtration area and no work done on liquid flowing through cake; thus (4) is a special case of

$$p_1 + \frac{\rho_f u_1^2}{2g_c} = p_2 + \frac{\rho_f u_2^2}{2g_c} + p_w - p_f \quad (6)$$

where in general

$$p_w = \frac{g}{g_c}\rho_f L \quad (7)$$

$$p_f = \frac{Q\mu\alpha W}{A^2 g_c} \quad (8)$$

Equation (6) simplifies to (4) when $u_1 = u_2$ and $p_w = 0$ as for Case 1, which follows.

The major problem under consideration in the following cases is interpretation of compression-permeability data on the cake over the pressure limits to yield a value of α holding for an actual filter cake over these limits. Final usage of this information to predict filtration rates under over-all Δp conditions will involve solution of (5) or (5*a*) also. This can usually be done directly with sufficient accuracy using measured R_m values for the used filter media. For cases where filtration area changes through cake or where work is done by gravitational field on liquid passing through cake, (6) will have to be written to define α, the average cake resistance value, and will not simplify to (4).

Case 1. Flat Filter Surface Oriented Vertically (Figure A1). For this case, (6) simplifies to (4) and α is defined as in the usual filtration-rate equation. The differen-

tial weight of cake solids dW within the differential cake thickness dL perpendicular to the direction of liquid flow is to be considered. Writing the energy-balance form of Bernoulli's equation over the cake increment for this simple case gives

$$-dp = \frac{Q\mu\alpha_p dW}{A^2 g_c} = dp_f \qquad (9)$$

where α_p is specific cake resistance of increment. For the instant considered, A and Q are constant, making the superficial velocity through the cake a constant. During actual filtration of finely divided solids, however, cumulative drag of fluid on pore walls results in a compressive pressure p_s acting, in the direction of flow, on the cake solids to cause consolidation. If consolidation results under this compressive pressure as with compressible cakes, $\alpha_p = f(p_s)$. For the simple case under consideration

$$dp_s = dp_f = p_2 - p_1 = -dp \qquad (10)$$

where dp_f is friction loss across cake increment and equals $-dp$ according to (9). The compressive pressure p_s acting in the direction of flow will vary from $(p_2 - p_1)$ at surface of filter medium to zero at surface of cake. Substituting (10) in (9) and employing these limits while integrating from cloth surface to cake surface gives

$$\int_{(p_2-p_1)}^{o} \frac{dp_s}{\alpha_p} = \frac{Q\mu}{A^2 g_c} \int_W^o dW = -\frac{Q\mu W}{A^2 g_c}. \qquad (11)$$

Substituting (4), which defined α for the case, for the right side of (11) gives

$$\int_o^{(p_2-p_1)} \frac{dp_s}{\alpha_p} = \frac{p_2 - p_1}{\alpha}, \qquad (12)$$

which can be evaluated numerically for α by applying Simpson's rule to the compression-permeability curve of $1/\alpha_p$ vs. p_s, as is done in the example shown in Exhibit B. For this case the solution of (12) is independent of W or L.

Case 2. Flat Filter Surface Orientated Horizontally. In this case acceleration of gravity acts in the direction of flow. Writing the over-all energy balance (6) for this case gives

$$p_1 = p_2 + p_w - p_f. \qquad (13)$$

Substituting (7) and (8) and rearranging gives

$$(p_2 - p_1) + \frac{g}{g_c}\rho_f L = \frac{Q\mu\alpha W}{A^2 g_c} \qquad (14)$$

which defines α, the average specific cake resistance for this case.

Considering an incremental cake thickness during any instant of a constant pressure filtration and writing the energy balance where α_p is the specific cake resistance of increment gives

$$-dp = -dp_s + dp_f \qquad (15)$$

or

$$-dp = -\frac{g}{g_c}\rho_f dL + \frac{Q\mu\alpha_p dW}{A^2 g_c}, \qquad (15a)$$

where A and Q are constant. However, for this case the gravitational field acts on both liquid within the cake and cake solids. For this case the mechanical compressive pressure acting on cake solids in the direction of flow results from both frictional drag dp_f and a compressive pressure dp_w resulting from weight of cake solids suspended in liquid under earth's gravitational field. Thus

$$dp_s = dp_f + dp_w \qquad (16)$$

where

$$dp_w = \frac{g}{g_c}(\rho_s - \rho_f)(1 - \epsilon_p)dL = \frac{g}{g_c}\left(\frac{\rho_s - \rho_f}{\rho_s}\right)\frac{dW}{A} \qquad (17)$$

For a given cake thickness, the over-all compressive pressure p_s can then be determined by integrating a combination of (15a) and (16),

$$-p_s = \int_{p_s}^{o} dp_s = \frac{g\rho_f}{g_c}\int_L^o dL - \int_{p_1}^{p_2} dp + \frac{g}{g_c}(\rho_s - \rho_f)\int_L^o (1 - \epsilon_p)dL \qquad (18)$$

Substituting (17) in (16) and employing the limits of o and p_s as determined by (18) gives

$$\int_{p_s}^{o} \frac{dp_s}{\frac{(\rho_s - \rho_f)g}{\rho_s g_c} + \frac{Q\mu\alpha_p}{Ag_c}} = A\int_W^o dW = -W. \qquad (19)$$

Substituting (14) for the right-hand side of (19) gives the expression to be solved for α as

$$\int_{p_s}^{o} \frac{dp_s}{\frac{(\rho_s - \rho_f)g}{\rho_s g_c} + \frac{Q\mu\alpha_p}{Ag_c}} = -\frac{Ag_c[(p_2 - p_1) + \frac{g}{g_c}\rho_f L]}{Q\mu\alpha} \qquad (20)$$

Equation (18) cannot be integrated without knowledge of $\epsilon_p = f(L)$, which is not available from compression-permeability data. When L is small compared to head represented by pressure drop $p_2 - p_1$, Equation (18) simplifies to Case 1 and $dp_s = -dp$. Equation (20) could be solved by trial and error and graphical integration of compression-permeability data if the limit p_s was established by (18). Equation (20) shows that for Case 2, α becomes a function of L and is no longer independent of cake thickness as in Case 1. If $(\rho_s - \rho_f)/\rho_s$ is small and $\rho_f L$ is small compared to $p_2 - p_1$, Equation (20) simplifies to Equation (12) as for Case 1. For most actual filtrations on a flat horizontal surface, therefore, Equation (12) can be used with little error.

Case 3. Cylindrical Filtering Surface, Axis Vertical, Filtering on Inside. In this case the acceleration of gravity is again perpendicular to direction of flow and has no net effect, but the effective area of the cake perpendicular to the direction of flow is changing. For the filter medium, which is of negligible thickness, the active surface area may be written as $A = 2\pi h r_o$ and this substituted in Equation (5) to give

$$p_1 - p_o = \frac{Q\mu K_m}{2\pi h r_o g_c}. \qquad (21)$$

Writing the over-all pressure balance [Equation (6)] for the cake in this case gives

$$p_1 = p_2 + p_v - p_f \qquad (22)$$

where p_v = pressure gain resulting from decrease in kinetic energy of liquid flowing through expanding cross section of cake, or

$$p_v = \frac{\rho_f(u_2^2 - u_1^2)}{2g_c} = \frac{\rho_f Q^2}{2g_c(2\pi h)^2}\left(\frac{1}{r_c^2} - \frac{1}{r_o^2}\right). \qquad (23)$$

For this case one can also write

$$W = \pi h\rho_s(1 - \epsilon)(r_o^2 - r_c^2). \qquad (24)$$

By substitution of (8), (23), and (24) in (22) the expression obtained for the over-all cake is

$$(p_2 - p_1) + \frac{\rho_f Q^2}{2g_c(2\pi h)^2}\left(\frac{1}{r_c^2} - \frac{1}{r_o^2}\right) = \frac{Q\mu\pi h\rho_s(1 - \epsilon)(r_o^2 - r_c^2)}{g_c}\left(\frac{\alpha}{A^2}\right), \qquad (25)$$

which defines both α and A for this case.

Considering an incremental cake thickness dr during any instant of a constant pressure filtration and writing the pressure balance where α_p is the specific cake resistance in the increment gives

$$-dp = -dp_v + dp_f \qquad (26)$$

For this increment $A = 2\pi hr$ and $dW = \rho_s(1-\epsilon_p)\,2\pi hr dr$. Also

$$u = \frac{Q}{2\pi hr}$$

$$du = -\frac{Q}{2\pi h}\frac{dr}{r^2}$$

and

$$dp_v = \frac{\rho_f u du}{g_c} = -\frac{\rho_f}{g_c}\left(\frac{Q}{2\pi h}\right)^2\frac{dr}{r^3}. \qquad (27)$$

Substituting in (26) gives

$$-dp = \frac{\rho_f}{g_c}\left(\frac{Q}{2\pi h}\right)^2\frac{dr}{r^3} + \frac{Q\mu\rho_s(1-\epsilon_p)a_p}{2\pi h g_c}\frac{dr}{r}, \qquad (28)$$

which is the general differential rate equation for this case.

For this case the compressive pressure acting on cake solids again results from friction loss dp_f and is caused by pressure drop dp and change in kinetic energy dp_v. From (26),

$$dp_s = dp_f = dp_v - dp. \qquad (29)$$

Substituting gives

$$\int_{p_s}^{o} dp_s = -\frac{\rho_f}{g_c}\left(\frac{Q}{2\pi h}\right)^2\int_{r_o}^{r_c}\frac{dr}{r^3} - \int_{p_1}^{p_2} dp, \qquad (30)$$

or integrating gives

$$-p_s = \frac{\rho_f}{g_c}\left(\frac{Q}{2\pi h}\right)^2\left(\frac{1}{r_c^2}-\frac{1}{r_o^2}\right) - (p_2 - p_1). \qquad (31)$$

which gives the maximum limit of p_s at filter medium, p_s being essentially 0 at surface of filter cake. Then substituting in $dp = dp_f$ gives

$$\int_{p_s}^{o}\frac{dp_s}{(1-\epsilon_p)a_p} = \frac{Q\mu\rho_s}{2\pi h g_c}\int_{r_o}^{r_c}\frac{dr}{r} = \frac{Q\mu\rho_s}{2\pi h g_c}\ln\frac{r_c}{r_o}. \qquad (32)$$

Substituting Equation (25) gives

$$\int_{p_s}^{o}\frac{dp_s}{(1-\epsilon_p)a_p} = \frac{\ln\dfrac{r_c}{r_o}}{2(\pi h)^2(1-\epsilon)(r_o^2-r_c^2)}\left(\frac{A^2}{a}\right)\left[(p_2-p_1)+\frac{Q^2\rho_f}{g_c(2\pi h)^2}\left(\frac{1}{r_c^2}-\frac{1}{r_o^2}\right)\right]. \qquad (33)$$

For any values of r_o and r_c, (31) and (33) can be solved by trial and error using compression-permeability data. A value of Q must be assumed, (31) solved, the left-hand side of (33) integrated graphically using compression-permeability data, a value of ϵ obtained for p_s from compression-permeability data, (33) solved for A^2/a, and this value substituted back in (25) to determine whether assumed Q is correct. A large amount of work, however, would be required for solution.

For the special case where r is large compared with the cake thickness $r_c - r_o$, the term $(1/r_c^2) - (1/r_o^2)$ becomes very small, and (31) simplifies to $p_s = p_2 - p_1$. For this same condition, (33) becomes

$$\int_{o}^{p_s}\frac{dp_s}{(1-\epsilon_p)a_p} = \frac{A^2}{\left[2\pi h\dfrac{(r_o-r_c)}{\ln\dfrac{r_o}{r_c}}\right]\left[2\pi h\dfrac{(r_o+r_c)}{2}\right](1-\epsilon)} \qquad \frac{p_2-p_1}{a}, \qquad (34)$$

which can be written as

$$\int_{o}^{p_s}\frac{dp_s}{(1-\epsilon_p)a_p} = \frac{A^2}{(A_{lm})(A_m)(1-\epsilon)}\frac{p_2-p_1}{a}. \qquad (35)$$

This can be solved directly for A^2/a from compression-permeability data and indicates that for these conditions the A^2 term of (25), (33) ,and (35) should be made up of the log mean cake area multiplied by the arithmetic average cake area. If this is accepted as the solution for the unknown effective cake A^2 term, and used in Equation (25), then Equation (35) simplifies to

$$\int_{o}^{p_s}\frac{dp_s}{(1-\epsilon_p)a_p} = \frac{p_2-p_1}{a(1-\epsilon)}. \qquad (36)$$

Thus for this special case, a becomes independent of r or Q if the A^2 term of Equation (25) is taken as $A_{lm} \times A_m$. Then $a(1-\epsilon)$ can be solved for directly from compression-permeability data using (36) and values substituted in (25).

For the general case of Equation (33), the value of a is dependent on cake thickness where the term for kinetic energy change in flowing liquid is not negligible.

Case 4. Cylindrical Filtering Surface, Axis Vertical, Filtering on Outside. The solution of this case is identical with the solution of Case 3 and all equations applying directly if nomenclature shown in Figure A1 is adhered to. Since for this case $r_o > r_o$ instead of $r_c < r_o$ as in Case 3, the numerical solution will differ in that the sign of the kinetic energy term will be reversed and p_v will tend to increase rather than decrease compression. Also, Equation (24) would read $W = \pi h\rho_s(1-\epsilon)(r_c^2 - r_o^2)$, and this would carry through remaining expressions.

Appendix B.—Calculation of Average Specific Cake Resistance in Pressure Filtration, by Use of Compression-Permeability Data (Filtration on Flat Vertical Surface)

In order to solve Equation (1) of this paper it is necessary to obtain the value for $a_p = f(p_s)$. Examination of the curves of a_p vs. p_s shows that a complete and accurate expression for this relationship cannot in general be secured in a single equation simple enough to permit formal integration of Equation (1). Such an expression can be obtained for only slightly compressible cakes but would have only very limited application. It is possible, however, to solve Equation (1) graphically by use of the compression-permeability data of a_p vs. p_s. The denominator can be integrated graphically applying Simpson's rule to a plot of $1/a_p$ vs. p_s. Physically, it is preferable to plot a_p vs. p_s, since this plot gives a more accurate indication of the zero intercept value than a plot of $1/a_p$ vs. p_s. Values of $1/a_p$ can be calculated from this plot, and Simpson's rule can then be applied in order to integrate the curve $1/a_p$ vs. p_s without actually plotting $1/a_p$ vs. p_s. Equation (9) can then be solved for each desired hydraulic-pressure drop Δp by use of the integrated value of the denominator for that particular Δp.

The application of this method will be illustrated by means of the data on G-60 Darco activated-carbon heels in water suspension. Figure B1 shows an arithmetic plot of a_p vs. p_s. The intercept of this plot at zero pressure stress is $a_p = 0.5 \times 10^{11}$ ft./lb. According to Simpson's rule, the area under the curve of $1/a_p$ vs. p_s can be expressed as

$$A = \frac{\Delta p_s}{3}\left(\frac{1}{a_{p_0}}+\frac{4}{a_{p_1}}+\frac{2}{a_{p_2}}+\frac{4}{a_{p_3}}+\frac{1}{a_{p_4}}\right),$$

where the area under any portion of the curve is divided into four equal increments of Δp_s. Dividing the hydraulic-pressure drop Δp by the area obtained

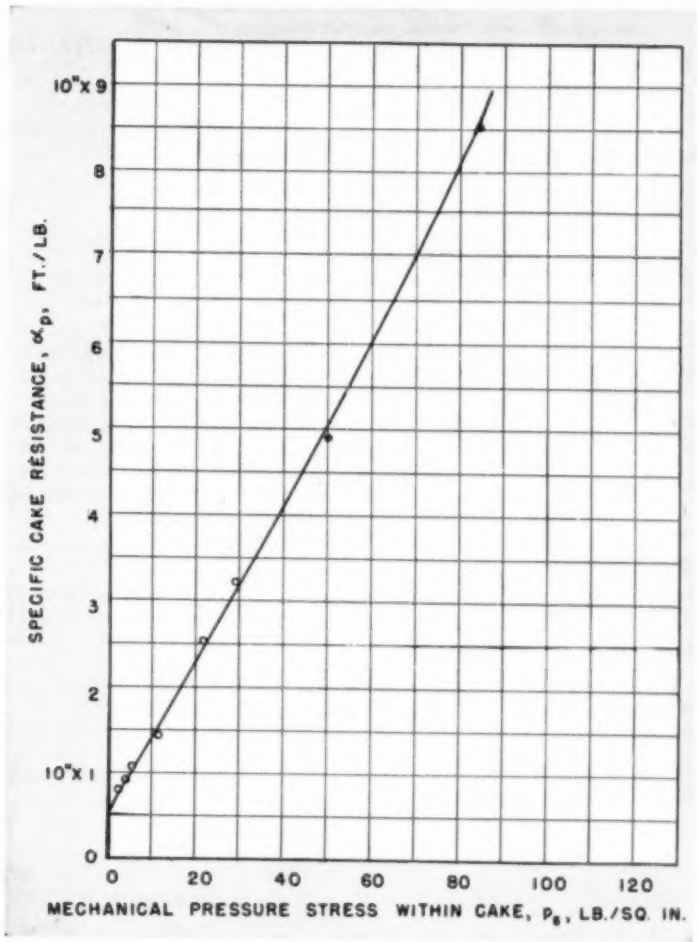


Fig. B1. Interpretation of compression-permeability data.

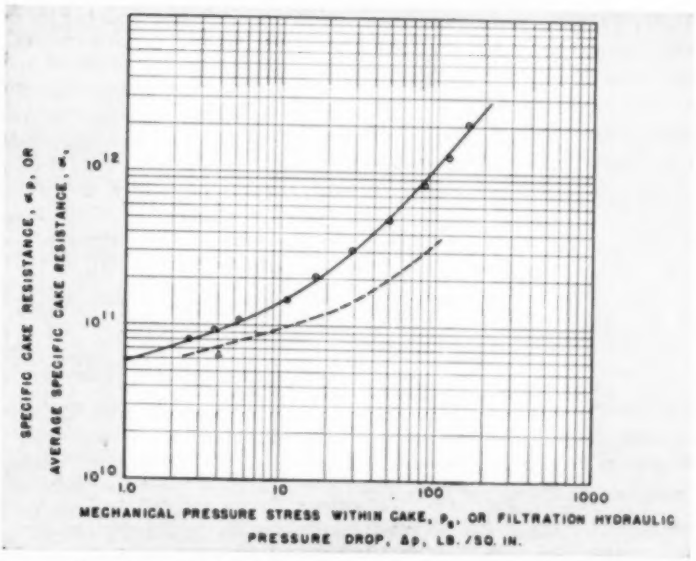


Fig. B2. Predicted filtration data from compression-permeability data.

over various limits of Δp solves Equation (9) directly.

For case of

$$\Delta p = 4.0$$
$$\Delta p_s = 1.0$$

p_s	$1/\alpha_p$	$f(1/\alpha_p)$
0	2.0×10^{11}	2.0×10^{-11}
1	1.66	6.72
2	1.33	2.66
3	1.16	4.64
4	1.05	1.05
		17.07×10^{-11}

Area $= 1/3 \times 17.07 \times 10^{-11}$

$= 5.69 \times 10^{-11}$

$$\alpha = \frac{\Delta p}{\int_0^{\Delta p} \frac{dp_s}{f(p_s)}} = \frac{4.0}{5.69 \times 10^{-11}}$$

$= 7.03 \times 10^{10}$

Similarly, for

$\Delta p = 12$	$\alpha = 1.03 \times 10^{11}$ ft./lb.
$\Delta p = 32$	$\alpha = 1.48 \times 10^{11}$ ft./lb.
$\Delta p = 80$	$\alpha = 3.07 \times 10^{11}$ ft./lb.

The curve of α vs. Δp plotted from the values calculated above is shown in Figure *B2*, together with the original curve of α_p vs. p_s.

The slope of α vs. Δp on a plot similar to Figure *B2* would be equal to that of α_p vs. p_s at any point for an incompressible cake. As the cake becomes more compressible, however, the slope of α_p vs. Δp_s becomes progressively greater than that of α vs. p_s at any point. Thus, the slope of the curve α_p vs. p_s can considerably exceed 1.0 without the compressibility factor s of the cake (slope of curve α vs. Δp) actually exceeding 1.0. At Δp and $p_s = 100$ lb./sq.in. (Figure *B2*), the slope of α_p vs. p_s is 1.15, whereas the slope of the α vs. Δp curve is only 0.81. At zero values of external pressure stress, either mechanical or hydraulic (as cake formed by sedimentation), the pressure stress within the cake will be very small (if the cake is thin), and the pressure stress and porosity distribution within the cake will approach uniformity, making α approach α_p for this condition. This condition agrees with the finding that the slope of the α vs. Δp curve is less than that for α_p vs. p_s for compressible cakes.

Part III will appear in an early issue.

Design of a ROTARY DRIER

G. Gutzeit and J. Robert Spraul

General American Transportation Corp., East Chicago, Indiana

G. Gutzeit

J. R. Spraul

G. Gutzeit, recently appointed associate director of General American Transportation Corp.'s research and development department in Chicago, Ill., was a member of the University of Geneva faculty from 1926 to 1941, during which time he served as a consultant for American, Swiss, French, Swedish, and Dutch firms. In 1941 he came to this country as development engineer in charge of metallurgical research, Dorr Co., Inc., and joined General American in 1944 as research director, process equipment division, New York. In 1945 he moved to East Chicago, Ind., as director of the research and testing laboratory. Born in Russia, Dr. Gutzeit was educated in Switzerland, receiving a Ph.D. in chemistry from the University of Geneva.

J. Robert Spraul, with General American Transportation Corp. since 1947, was recently appointed manager of the Corporation's research and testing laboratory. A graduate of Indiana University where he took a Ph.D. in physical chemistry in 1941, he subsequently taught chemistry in the extension division of the University for a year, and later held positions in the research department of the American Can Co. and as supervisor of physical chemical research at Armour Research Foundation.

In the course of technological evolution it frequently happens that processes or equipment developed in one specific field or for a specific purpose are particularly adapted to the solution of unrelated problems. The flotation cell, for instance, primarily a tool for mineral concentration, has been successfully used to separate lanolin from wool-scouring liquors or to manufacture guanidine carbonate.

General American's Type H rotary drier was originated in connection with an agricultural - chemurgic problem, namely, the continuous drying of alfalfa for the purpose of producing a stable, vitamin-rich feed meal.

Within the past twenty years the drying of forage crops, such as alfalfa, has changed from sun-drying operation to the use of various dehydrating machines. Rotary driers are one type of machine which has been used extensively for this drying operation. The basic theory of rotary driers is described, for instance, by Perry (*8*) and constructional details have been given by Gutzeit and Spraul (*4*). This paper reports the development of a rotary machine for the production of high-grade alfalfa, which subsequently has shown promise for the solution of drying problems in the chemical, pharmaceutical and distilling industries.

Alfalfa is a relatively difficult material to dry in view of (1) its physical heterogeneity; (2) the presence of, and hence the desire to preserve, oxidation sensitive vitamins; (3) the heat sensitivity of the chlorophyll and, to a lesser degree, of the cellulosic fiber and, (4) the necessity for low-cost, efficient methods of drying.

To comment further on these difficulties, it should be pointed out that alfalfa as mowed and chopped in the field consists of leaves and stems. The leaves, being thin, dry rapidly and will burn easily if not removed quickly from the drying medium. The stems provide a virtually impervious casing in which the moisture is trapped by the closing of both ends in chopping. This means that residence time in the drier must be short for leaves and long—to permit diffusion of moisture—for stems.

It was around 1945 that the full value of carotene (pro-vitamin A) content began to be realized. About this time also, buying of dried alfalfa was placed on a "bonus for carotene" basis. Both crop condition and drying affect the amount of carotene present in the dehydrated product. Excessive material

temperature and exposure time to heat tend to decompose the vitamin in the drier.

Low-cost, efficient operation dictates direct heating with combustion gases. Size of equipment must be small for tonnage produced; hence, high temperatures must be employed.

In 1936 Louisville Drying Machinery Co., now a div. of General Am. Transportation Corp., designed and built a unit to handle unchopped alfalfa for a small farm operation. The unit was hand-fed and coal-stoker fired. The combustion gases entered longitudinal ducts arranged around the interior periphery of the revolving shell. These gases heated the entering feed by conduction through the ducts for the first 5 ft. of the cylinder and then expanded into the full shell as in a conventional parallel-current direct-heat unit. This machine was 6 ft. in diam. and 50 ft. in over-all length and the rated capacity was relatively low. This was due partly to handling unchopped material, partly to nonuniform heating and poor temperature control. The drying cost was high, the product quality was poor and the operation was not a success.

This unit was subsequently sold to a farm in Chesterfield, Mo., and in 1946 General American was requested to provide technical assistance in improving operation. After simple rudimentary changes, production was increased 600 to 700 lb. of dry product/hr.

During the winter of 1946-47 radical changes in the internal structure of the unit were made for the 1947 season. Use of various internal arrangements in rotary driers is not new in itself, as evidenced by the patents which have been granted in this field (*1-2, 5-7, 9*). However, many previous adaptations were either limited or specific in their action, or the design was complex and led to excessively high construction costs.

The first two changes made in the unit mentioned were the removal of the 5 ft. of duct-fitted section which reduced the length to 45 ft., and the installation of propane gas burners and a suitable combustion chamber. Retainer rings were then placed in the drier at regular intervals for the purpose of increasing the retention time.

This purpose was accomplished, but the inlet air temperature had to be limited to a relatively low value to avoid scorching or burning. Circular baffles (seven in number) were then installed between each pair of retainer rings with the last two not circular but doughnut-shaped. These baffles were of 4 ft. diam. suspended at three points from the cylinder. The last two had 2-ft. diam. holes. Originally, conical baffles were contemplated, but were abandoned for flat plates of much simpler and more inexpensive fabrication. The goal of these additions was to increase retention time further without sacrificing the amount of air that could be handled, and thereby maintain a good production rate at the lower inlet air temperatures required by the changes.

The result of these alterations was unexpected since the retention time was decreased instead of increased. This was due to the fact that high air velocities prevailed around the retainer rings and the baffles. At these points the material became airborne and moved forward rapidly for a short distance with the air stream instead of depending on showering and the slope of the drier for its movement. Despite the shortening of the retention time, the production rate was increased remarkably due to two effects obtained by the baffle and dam arrangement. The internal structure introduced radiating surfaces which enhanced the heat-transfer rate, and the frequent changes of relative velocities between material and air increased the rate of evaporation. Since the material was easily airborne, the conventional discharge hood was removed and a conical section was attached to the exhaust end of the drier discharging both the material and the gases into a cyclone so that all the material would be collected at one discharge point. All of these structural features were incorporated into a patent application which has recently been granted (*1*). Typical operating data on the unit are given in Table 1.

Table 1

TYPICAL OPERATING DATA ON 6 FT. × 45 FT. TYPE H DRIER

Feed rate, lb./hr.	5,510
Feed moisture, % wet basis	73
Product moisture, % wet basis	5–7
Production rate, lb./hr. at 8% moisture	1,600
Inlet air temp., °F.	1,700
Outlet air temp., °F.	250
Product temp., °F.	145
Lb. H_2O evaporated/hr.	3,910
Exhaust air volume, cu.ft./min.	8,450

Sugar Land, Tex., Drier

A second unit was then designed and fabricated having the dimensions of 8 ft. in diam. and 60 ft. in length. The sizes of all internal parts, namely baffles, dams, and flights, were scaled up in straight ratio to the first unit. The two doughnut-shaped baffles were replaced with solid circles. Natural-gas combustion was used with Venturi-type burners. The same type of conical discharge was employed and, in sizing the exhauster, a safety factor of 25% was added. The material was fed from the cyclone discharge to a hammer mill and the meal produced was then bagged.

In the plant startup a great deal of mechanical trouble was experienced with the wet material feeding equipment. The initial arrangement provided a silage mill at the drier site to chop the field-cut alfalfa on the assumption that the second chopping would provide a wet feed of smaller average particle size, hence easier to dry. The arrangement also provided for blowing the rechopped material to a small cyclone collector from which the material was intended to drop into the drier feed chute.

As received from the field the chopped alfalfa contained considerably more moisture than had been anticipated and, when the material was rechopped, so much moisture was released mechanically that it promptly clogged the cyclone collector.

The rechopping operation, which proved to have more nearly a pulping effect, was therefore abandoned and the material fed direct to the drier as received from the field. In this condition it has an average stem length approximately one inch. Considerable mechanical difficulty was also experienced with the automatic feeder, which was intended to receive the field-chopped material by truck load and feed it continuously and uniformly to the drier. The original design of the feeder was inadequate and it was impossible to feed the material to the drier at a uniform rate. The feeder was eventually replaced with an entirely new one of a design based on the experience with the original inadequate one.

The excess air volume pulled by the exhauster, because of the incorporation of a 25% safety factor gave an extremely short retention time of 30-60 sec. This led to a high exhaust temperature and produced a hot but wet material which was difficult to grind and which overloaded the hammer mill. Under these conditions the control system was too sluggish.

The exhauster was slowed to obtain the same shell velocity as used in the original unit. This produced good control with modulating equipment. It was found both in this plant and in pilot-plant tests, which are discussed later, that shell velocity is more critical than in conventional equipment; however, at the correct velocities the equipment responded readily to control instruments.

As originally installed, the firing equipment produced a flame too long for the combustion chamber so that there was flame propagation into the drier shell with attendant scorching of the material at this point. To correct this, strip burners were added to divide the flame from a few long ones into a multiplicity of much shorter ones. This eliminated the flame propagation into the drier cylinder and also eliminated the scorching of the alfalfa.

A good deal of slugging in the exhauster was noted, and lifting flights were installed in the cone section to smooth the flow of material into the air stream. Prior to this change, the material collected at the discharge cone until a sufficient velocity was obtained

due to the reduced cross section. The drier would then purge itself in a slug to the exhauster.

Although the product temperature was quite low for direct-heat drier practice, this temperature proved a bit high for storage after the material had been further heated by the milling operation. A pneumatic-conveying system therefore was added between the drier cyclone and the hammer mill, using atmospheric air to cool the material in transit. It was found that additional drying could be obtained in this system by balancing the amount of cooling air against the drier exhaust conditions. In other words, lower exhaust temperatures, accompanied by lower stack losses together with lower product temperature, produced wetter material which aided the cooling operation by the evaporation of water during the cooling cycle. Thus capacity was increased and fuel consumption lowered.

OPERATIONAL DATA ON TYPE H ALFALFA DRIER

Two studies of the drier operation, after the required changes were made, have been conducted. The first survey was made for a one-week period in the spring of 1949. At this time the drier was not insulated, and the data taken consisted of inlet and outlet air temperatures, inlet and outlet material moistures, exhaust gas volume, production of alfalfa and gas consumption. The inlet air temperature was determined by a thermocouple enclosed in an armored shield which was placed in the end of the combustion chamber nearest the drier and close to the feed chute opening. The thermocouple bead was located at the approximate center of the combustion chamber circumference, and the temperature was read from an indicating pyrometer. The outlet air temperature was determined by inserting a thermometer into the duct work just preceding the fan. Material moistures were determined by heating representative samples to constant weight in an oven at 100° C.

The air volume was calculated from the fan data after determining horsepower consumption and static pressure. The design figure of 13,400 cu.ft./min. was found to be correct. The volume obtained was checked with pitot tube

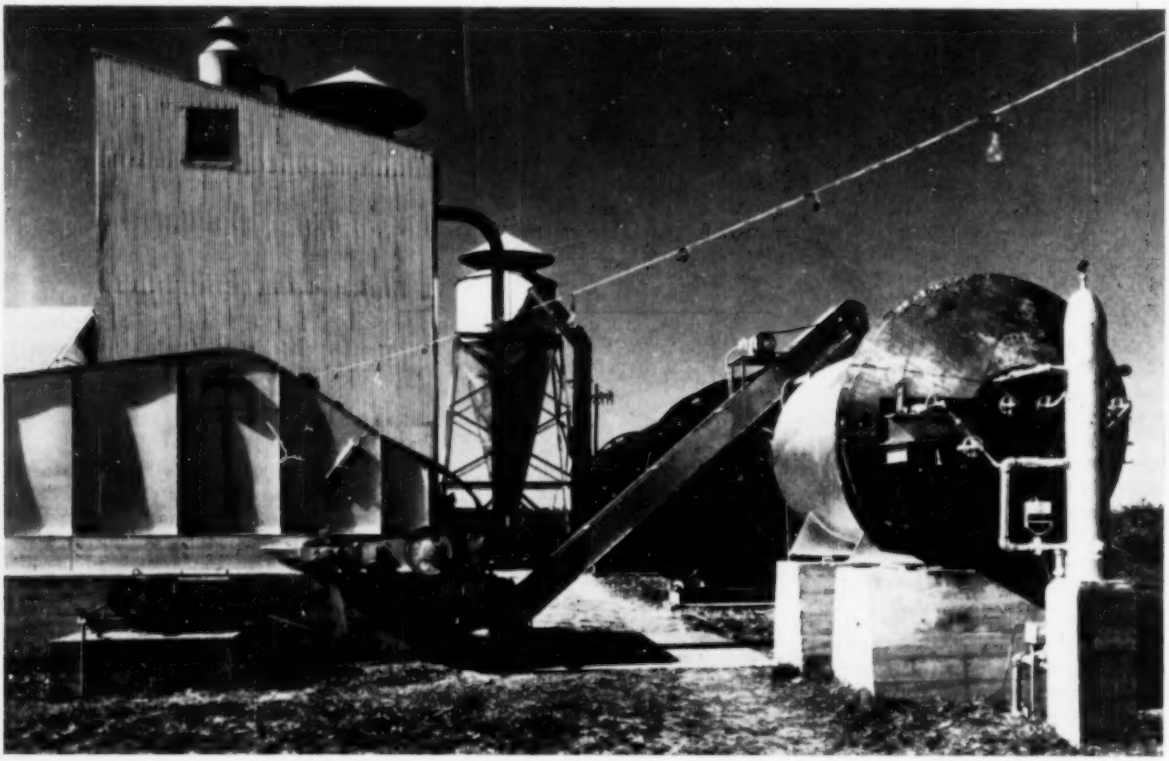


Fig. 1. Sugar Land, Tex., installation.

Table 2

DRIER DATA FOR APRIL 7-11, 1949

(8 FT. × 60 FT. TYPE H UNIT AT SUGAR LAND, TEX., HANDLING ALFALFA)

	APRIL 7	APRIL 8	APRIL 9	APRIL 10	APRIL 11
Avg. hourly gas consumption cu.ft./hr. at 4-oz. gauge pressure	16,831	17,345	17,037	16,712	16,339
Avg. heat input, B.t.u./hr.	17,403,254	17,934,730	17,616,258	17,280,208	16,894,526
Lb., water evaporated/hr. (avg.)	7,700	7,800	8,130	7,910	7,440
Feed moisture, % (avg. for day)	80	82	83	82	82
Product moisture, % (avg. for day)	10	10	9	9	10
Average production/hr. (100 lb. bags)	22	19.5	18.7	19.5	18.6
No. of hr. drier data taken	9	9	9	8	8
Inlet air temp., ° F.	1,700	1,700	1,750	1,810	1,600
Outlet air temp., ° F.	225	220	230	240	215
B.t.u./lb. of water evaporated	2,260	2,299	2,167	2,185	2,271

Table 3

DRIER DATA FOR MAY 10-17, 1950

(8 FT. × 60 FT. TYPE H UNIT AT SUGAR LAND, TEX., HANDLING ALFALFA)

	MAY 10	MAY 11	MAY 12	MAY 13	MAY 15	MAY 16	MAY 17
Avg. hourly gas consumption cu.ft./hr. at 4-oz. gauge pressure	12,925	13,078	15,606	10,827	12,542	13,074	10,880
Avg. heat input, B.t.u./hr.	13,364,450	13,522,650	16,136,600	11,205,460	12,968,430	13,518,515	11,249,920
Lb. water evaporated/hr. (avg.)	7,314	6,287	8,143	6,063	5,533	7,190	5,380
Feed moisture, % (avg. for day	79	79	82	81	78	79	83
Product moisture % (avg. for day)	9.5	10.0	10.0	9	10.0	11.0	14.0
Average production/hr. (100-lb. bags)							
Leaf meal	19.5	17.3	19.1	15.25	17.1	21.0	12.5
Stem meal	2.6	1.83	1.25	0.75	0.8	1.2	0.75
B.t.u./lb. water evaporated	1,827	2,151	1,982	1,848	2,343	1,880	2,091
No. of hr. drier data taken	8.5	6.0	8.0	4.0	8.0	5.0	4.0
Inlet air temp., ° F.	1,510	1,510	1,700	1,320	1,500	1,500	1,300
Outlet air temp., ° F.	200	210	205	210	205	195	210

measurements, but the accuracy of this method was limited due to bends in the duct work and to the airborne material. The production rate was determined by a count of the number of bags of alfalfa produced over a unit period of time, and the gas consumption obtained from gas-meter readings.

The operational data for the period April 7-11, 1949, are given in Table 2. These figures are averages for an entire day's run, and they are based on data taken every hour. There is some variation from hour to hour.

Early in 1950 the drier shell was covered with a 2-in. thickness of asbestos insulation. A photograph of the installation is given in Figure 1. A second set of data was obtained during the period of May 10-17, 1950, for the purpose of determining the effect of the insulation. These data are summarized in Table 3, and again they are an average of a day's operation where readings were taken every hour. For these tests the moisture contents of the drier feed and product were determined in a forced draft moisture teller using 350° F. air until the sample reached constant weight. The reason for the wider variation in the inlet air temperatures during the 1950 test period was that the effect of inlet air temperature on the carotene content was being investigated. It was found that, if the drier was operated properly, the carotene content of the drier product varied with the character of the field of alfalfa and not with the inlet air temperature between 1300 and 1700° F. The low throughput on May 15 is explained by the fact that the field was cut on that day which was high in grass content and this lowered the drying rate and gave a product with a low carotene content.

One change in operating practice was incorporated at the same time the insulation was applied. The dried alfalfa was separated into leaf and stem meal to upgrade most of the product. The separation is made by a sifting screen located below the hammer mill cyclone. The screen has 1/16-in. holes with six openings to the inch. The material which passes through the screen is collected as leaf meal, and the oversize enters another discharge spout and is collected as stem meal. The reason for this separation is that most of the carotene is present in the leafy portion of the plant. The premium being offered for high carotene content during this period justified this method of upgrading the major portion of the product at the sacrifice of around 10% or less of the meal.

Because of the change in operating procedure, it is difficult to evaluate the effect of the insulation. A comparison of the 1949 and 1950 figures for British thermal units per pound of water evaporated does give a picture of the advantage thus obtained. In 1949 the average figure for the five-day test period was 2,236 B.t.u./lb. of water evaporated and in 1950 this average figure was 2,017, including the data for May 15 where a feed high in grass was used. This is a decrease of 9.8% based on the 1949 average. Actually in 1950, the drier was operated generally at 1,500° F. inlet temperature instead of 1,700° F., and, under these conditions, the unit used approximately 3,000,000 B.t.u./hr. less gas and gave approximately the same amount of drier product.

STATIC PRESSURE CHARACTERISTICS

The internal structural features of the Type H drier lead to a high static pressure drop across the machine. The Sugar Land, Tex., unit has a static pressure drop to the atmosphere of 9.5 in. of water through the whole system including the cyclone. Of this total, 7.5 in. is the pressure drop across the drier, 1.5 in. across the cyclone and 0.5 in. across the combustion chamber.

CHARACTER OF EXHAUST GASES

The gases drawn through the drier consist of heated air, water vapor evaporated from the alfalfa, and carbon dioxide, nitrogen and water vapor from the combustion of the gas. A fan is a volumetric machine, pulling a definite volume of gas, and it is of interest to determine the character of the gases discharged. At Sugar Land the fan is rated at 13,400 cu.ft./min.

Assuming certain representative conditions such as an hourly evaporative capacity of 7,000 lb. of water, an exhaust temperature of 212° F., a gas consumption of 13,000 cu.ft./hr. (4 oz. gauge pressure); it is possible to determine qualitatively the composition of the exhaust gases. At 212° F., 7,000 lb. of water vapor/hr. will occupy 3,125 cu. ft./min. Assuming that the heating gas is 100% methane (80-85% is more probable), it will require 2 cu.ft .of oxygen for every cubic foot of gas used; or, since air is 20% oxygen, ten volumes of air will be required for every cubic foot of gas. For 13,000 cu.ft./hr. of gas, 130,000 cu.ft./hr. of air will be needed, or a total of 143,000 cu.ft./hr. Every volume of gas will produce two volumes of water vapor or 26,000 cu.ft./hr. will be developed from the combustion. This is equivalent to 433 cu.ft./min. at 212° F. Thus, a total of 3,558 cu.ft./min. of water vapor will be exhausted by the fan. For every volume of gas consumed there will be eight volumes of

Table 4.—External Surface Temperatures of Drier Component

COMPONENT	INLET AIR TEMPERATURE, ° F.				SURFACE AREA SQ.FT.
	1300	1500	1500	1700	
Combustion chamber					258
Burner end	250	350	350–400	400–500	
Drier end	150	200–250	300–350	450–500	
Breeching	150	200–250	350–400	500	48
Front end of drier	175	200–250	–	350–400	35.4
Dryer shell (front)	125	125–150	125–150	150	1600 (total area)
Exhaust fan	150	150–175	–	175–200	

nitrogen remaining from the air which has furnished oxygen for combustion. This constitutes 1,733 cu.ft./min. and carbon dioxide furnishes an additional 217 cu.ft./min. Thus, the exhaust gas has an approximate composition in cubic feet per minute and volumetric per cent as shown in Table A.

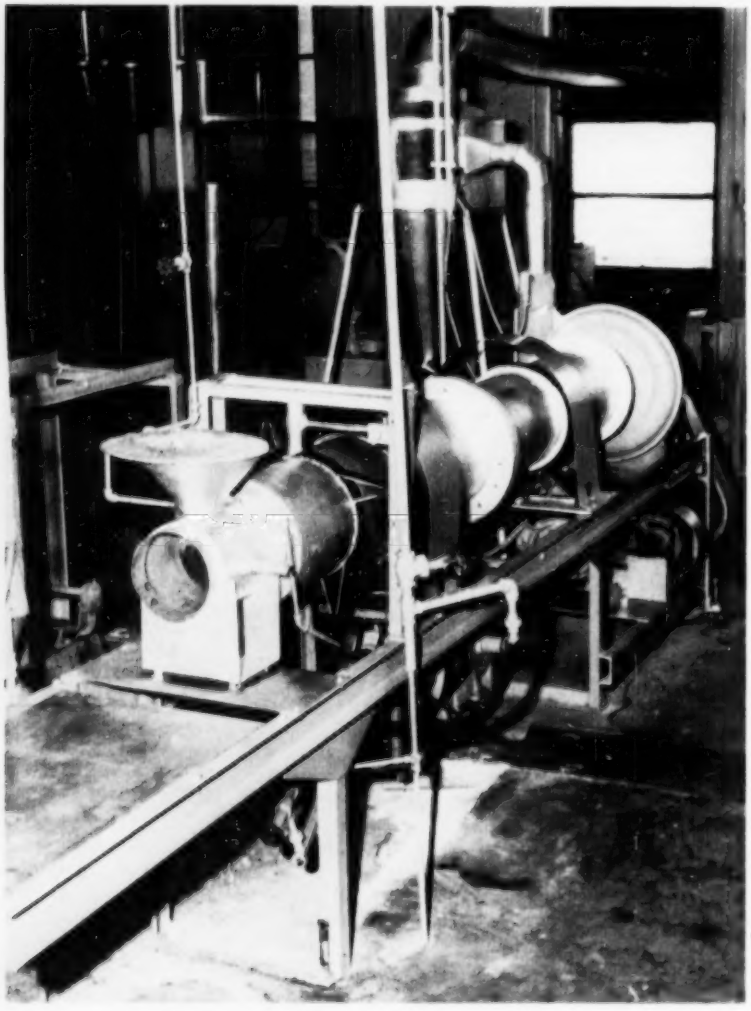


Fig. 2. 1 ft. × 8 ft. pilot plant unit.

Table 5.—Pounds of Water Evaporated Per Hour

Air velocity, ft./min.	WOOD FLOUR		BREWER'S GRAINS			ALFALFA	
	280	200	330	280	200	280	200
Inlet air temp. (° F.)							
800	71.3	47.1	46.8	52.9	46.6	14.3	18.0
1000	81.9	63.1	67.8	66.4	60.2	25.6	29.2
1200	108.1	78.5	....	77.7	68.9	29.0	....

Air velocities calculated for room temperature conditions through a 1-ft. diam. shell.

Table 6.—Fan Data on 1 ft. x 8 ft. Pilot Plant Unit

FAN REV./MIN.	HP.	AIR VELOCITY IN DRIER FT./MIN.	STATIC PRESSURE IN. OF WATER	
			BEFORE FAN	AFTER FAN
832	.54	204	— .6	.17
1335	.70	294	—1.5	.40
1790	1.05	384	—1.8	.80
2115	1.40	456	—4.2	1.10
2200	1.61	470	—4.2	1.40

Table A

COMPOUND	CU.FT./MIN.	%
Water	3,558	26.6
Carbon dioxide	217	1.6
Nitrogen (from combustion)	1,733	12.9
Air (heated)	7,892	58.9

From the above data it can be calculated that with an ambient air temperature of 80° F., there is a stack loss of 1,650,000 B.t.u./hr. or 12.3% of the heat input.

RADIATION LOSSES

Using Tempilstiks, temperatures of the exterior surfaces of the combustion chamber, breeching, front end of the drier and drier shell were approximated. These results are given in Table 4 for three different inlet air temperatures. Two sets of data are given for 1,500° F. inlet air temperature to show the variations obtained and the surface area of the component parts is included.

Using an emissivity of 0.8 (this figure probably is low for the drier shell and high for the other components), and selecting the following temperatures for the component parts: combustion chamber, 450° F.; breeching, 500° F. front end of drier, 400° F.; total drier shell, 150° F.; a total radiation loss of 435,000 B.t.u./hr. is calculated. This excludes any losses from out the front of the combustion chamber and around the fan and cyclones.

Pilot Plant Studies

In 1948 a 1-ft. diam. by 8-ft. long pilot-plant unit was constructed for the purpose of more thoroughly studying the characteristics of this machine. The drier was equipped with lifting flights and the baffles and dams were structurally arranged in the same dimensional ratios as had been used in the field. The combustion chamber was insulated and the heat was furnished by a ring-type gas-burner giving a short flame length and rated at 300,000 B.t.u./hr. A Buffalo 5E exhauster operated with a variable speed motor discharged the exhaust gases and material into a cyclone. A photograph of this unit is shown in Figure 2.

The first series of tests conducted with this unit was with 80-mesh wood flour having a feed moisture to the drier of about 75%, and a product moisture of 8-10% was desired. The effect of air velocity changes at different inlet air temperatures was determined, and it was found that at any particular air velocity or volume, the Type H unit had a higher capacity than a regular parallel-current unit of the same size. This increase in capacity was obtained at least partially through the fact that the Type

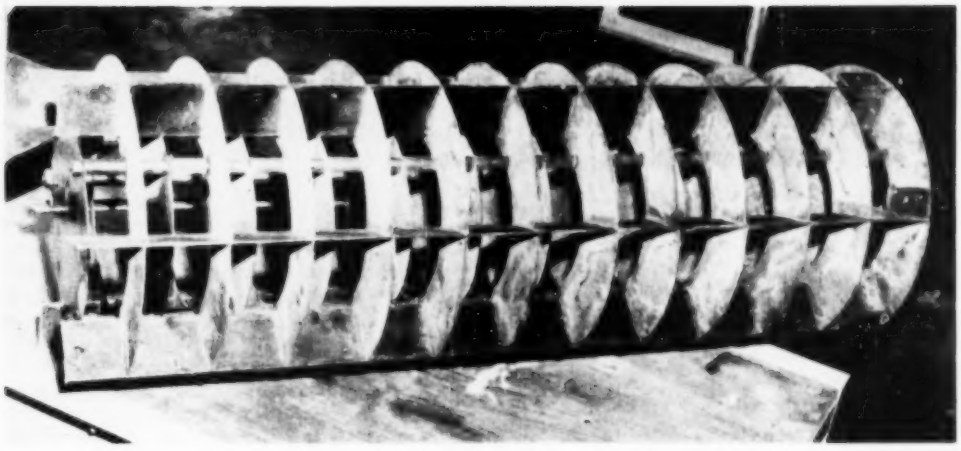


Fig. 3. Internal structure for flexible unit.

H unit permitted operation at lower exhaust air temperature and still would yield a product having the required moisture content. It was also found that the internal arrangement permitted the use of higher air volumes with the usual length to diameter ratio of six or eight to one over what could be used with a parallel-current unit at the same ratio. In the latter, the length would have had to be increased considerably to permit efficient operation.

As is the case with all parallel flow hot-air driers, there is a maximum air velocity for each particular material and this depends upon the particle size and diffusion characteristics of the material. When this critical air velocity is exceeded, the material is blown through the drier before it is properly dry. The exhaust air temperature is high, resulting in high-stack losses and thus low thermal efficiencies. The material itself frequently is hot even though it is still relatively wet. In a regular parallel-current machine the only way to overcome these conditions is to extend the length of the drier or use a larger diameter.

Data to show the effect of air velocity on the capacities obtained in the 1 ft. × 8 ft. pilot-plant unit for three different materials are given in Table 5. The feed moisture in all cases was about 70% and the products contained 8 to 10% water. The increase in air velocity (through a 1-ft. diam. shell) from 200 to 280 ft./min. gave an appreciable increase in the pounds of water evaporated per hour with wood flour at each inlet air temperature. With brewers grains this increase is smaller with the same increase in air velocity and with alfalfa there is a decrease in capacity at the higher air velocity. These data on alfalfa verify the field results obtained at Sugar Land. With brewers grains a further increase in air velocity to 330 ft./min. again produced the decreased capacity phenomenon which was demonstrated with alfalfa at lower velocities. The critical air velocity for any particular material is higher at higher inlet air temperatures.

The relationship of air velocity with the fan characteristics and the static pressure has been studied for the pilot plant unit. These data are given in Table 6. The drier velocity is given in feet per minute through a 1-ft. diam. shell. All measurements were taken with a 10-ft. straight pipe section attached to the exhaust side of the fan. The air velocity was determined by pitot-tube traverses in this pipe section under room temperature and humidity conditions. The introduction of the cyclone into the system would increase the static pressure somewhat and change the other values accordingly.

For purposes of demonstration, a small drier 5 in. in diam. and 36 in. long was constructed with a glass shell for visual display of the action of the material in this type of unit. In checking the operation of this small drier, it was noticed that the material appeared dry enough for partial fluidization for the last two thirds of the drier length. It appeared that the drier length might be shortened by placing the baffles and dams closer together at least for the last one half of the drier length. A pilot-plant unit was constructed for the purpose of investigating the structural relationship between the baffle and dam positions and the drier length.

The unit consists of a section 1 ft. in diam. by 4 ft. long and two sections 1-ft. in diam. by 1-ft. long. Each of these three sections was equipped with flanges so that they could be bolted together to produce units 4, 5 and 6 ft. long. An 8-in. long section having spiral flights but no baffles or dams was always placed between the feed chute and the first part of the drier shell proper. The purpose of the spiral flight section was to move the material away from the feed chute rapidly and this action was particularly important at some of the high feed rates used.

The pilot unit was constructed so that the internal structure including lifting flights could be removed from the two 1-ft. sections and the 4-ft. length. By means of pipe lengths the positions of the baffles and dams could be varied to obtain a wide variety of internal arrangements. A photograph of a typical internal structure is given in Figure 3. The closer the baffles and dams are placed together, the higher becomes the static pressure and more horsepower is required to run the fan to obtain the same air velocity. This increase in power requirements must be balanced against the saving obtained from a lower initial investment because of a small drier.

The first material investigated in the flexible unit was 80-mesh wood flour. Water was mixed with the wood flour to give a moisture content of 70-75% and the mixture was allowed to stand overnight to permit good diffusion of the moisture through the material. The actual tests were conducted essentially by the technique described by Friedman and Marshall (9) except that the drier was fed by weighing the material instead of by volume. Weighed portions were added every minute.

The first structural arrangement selected for investigation included the 4-ft. section with 8-in. spiral feed section attached, giving a drier 4 ft., 8 in. long by 1 ft. in diam. The dam rings were 6 in. apart and the baffles were placed 2 in. behind the dam rings. Eight baffles and eight dam rings were used, and their dimensions were 12 in. O.D., 6⅝ in. I.D. for the dam rings and 7½ in. O.D. for the baffles. With this arrangement runs were made at inlet air temperatures of 400, 800, 1,200 and 1,600° F. at three air velocities: 250, 450 and 585 ft./min. These velocities are those obtained at room-temperature conditions and should be adjusted for the particular exhaust conditions in each test. For each velocity the revolutions per minute of the fan were constant for all tests. Results are given in Table 7; they show that the short unit can handle good capacities of this material even at elevated temperatures, except that at an inlet air temperature of 1,600° F., the exhaust air temperature is high for a material of this par-

Table 7.—Drying of 80-Mesh Wood Flour in 1 ft. x 4 ft. 8 in. Pilot-Plant Unit

DAM RINGS 6 IN. APART, BAFFLES 2 IN. BEHIND DAM RINGS

TEST NO.	FEED RATE LB./HR.	FEED MOISTURE %, WET BASIS	PRODUCT MOISTURE %, WET BASIS	FEED TEMP. ° F.	PROD. TEMP. ° F.	AIR TEMP., ° F. INLET	AIR TEMP., ° F. OUTLET	AIR VEL. FT./MIN.
1	25	72.5	3.0	70	110	400	175	250
2	30	72.5	4.0	70	120	400	220	450
3	45	72.5	5.6	70	120	400	225	580
4	45	73.5	11.1	70	120	800	192	250
5	80	73.5	9.2	70	130	800	210	450
6	105	73.5	4.5	70	150	800	265	580
7	90	73.4	8.2	70	130	1200	225	250
8	135	73.4	3.5	70	150	1200	275	450
9	150	73.8	5.5	70	130	1200	220	580
10	125	75.9	6.2	70	150	1600	265	250
11	175	73.9	8.5	70	160	1600	275	450
12	180	75.9	2.6	70	150	1600	260	580
			1 FT. × 5 FT. 8 IN. PILOT-PLANT UNIT					
1	40	76.6	10.3	68	130	800	205	210
2	70	76.8	12.2	65	122	800	172	340
3	100	75.5	8.2	70	125	800	194	415
4	100	76.8	12.8	70	125	1200	200	210
5	120	75.1	8.2	65	130	1200	220	340
6	150	75.4	5.3	73	135	1200	238	415

Table 8.—Baffle Temperature, °F. Numbered Front to Rear

TEST NO.	INLET AIR TEMP. ° F.	1	2	3	4	5	6	7	8	OUTLET AIR TEMP., ° F.
1	400	295	285	245	230	200	190	185	180	175
2	400	330	315	300	280	250	237	225	222	220
3	400	330	310	275	260	235	230	230	227	225
4	800	445	420	325	300	267	232	210	210	192
5	800	450	430	377	330	320	267	230	210	210
6	800	500	465	410	385	340	320	305	275	265
7	1200	665	590	410	350	290	257	240	230	225
8	1200	719	675	507	450	340	325	295	285	275
9	1200	665	580	525	420	320	290	230	220	220
10	1600	810	705	477	400	335	295	272	270	265
11	1600	800	730	560	505	425	385	320	282	275
12	1600	810	732	610	505	382	290	260	260	260

ticle size and drying characteristics. Comparative tests at slightly different air velocities for a unit having a 5 ft. 8 in.-length are given for comparison.

The temperature of each baffle was at least approximated during the twelve runs described in Table 7 by the following technique:

A constantan wire was fused to the back of each of the eight baffles at its center with a welding torch. The wires were insulated with liquid porcelain, and after the assembly was replaced, they were allowed to protrude through holes already provided at both ends of the rotating shell. A constantan wire attached to each protruding end and fastened around the shell served as a slip ring. Eight individual rings were thus provided, and iron-constantan standardized potentiometer readings were taken during a test by holding a contact wire against each ring. The drier itself was used as the iron element and a sliding contact on one of the drier flanges was continuously attached to the other potentiometer terminal. The readings obtained are given in Table 8 with the run numbers corresponding to those used in the previous Table 7. The accuracy of these temperature readings was checked by making Tempilstik markings on the back of each baffle before several of the tests and removing the internal structure for examination of the markings after the test. In each of these check tests the drier was brought up to operation temperature by starting with the drier partially full of wet material and beginning with a low inlet temperature. The test was stopped by a reverse of this procedure. The Tempilstiks verified the potentiometer readings within 50-100° F. at the higher temperatures and within 25-50° F. or less at the lower temperatures. It is interesting to note that the decrease in temperature is about 50% for the higher inlet air temperatures through the first 16 in. of the drier length. The inlet air temperature is obtained by a thermocouple directly below the feed chute opening.

A number of tests have been conducted on brewers grain using various structural arrangements and these results are compiled in Table 9. In the first series of tests (Nos. 1-8) it can be said that the structural arrangement is sufficiently close to give proper drying conditions. As the air velocities and inlet air temperatures increase, the exhaust air temperature rises and it would be considered almost too high for efficient operation in Tests 4 and 8. In the second series (Tests 9-12) where the distance between the baffles has been increased, the exhaust temperatures become excessive with resulting lower efficiency even at 360 ft./min. air velocity. The addition of length to the drier, as in Tests 13-16, with the same internal dimensional arrangement, further increases capacity and efficiency. In the original 1-ft. × 8-ft. unit comparable capacities are obtained, and here again excess air velocities lead to high exhaust temperatures as in Tests 18 and 19.

Representative runs for four materials in different pilot plant units are given in Table 10. Of particular interest are the two different tests with corn germ. The 210 ft./min. air velocity used in the first test recorded was about the maximum allowable in the short unit with relatively wide spacings. By adding one foot in length and decreasing the distance between the baffles and dams, a much higher air velocity can be used with a resulting increase in feed rate. Materials reported are typical of the type for which the Type H unit is especially adapted.

Drying of Antibiotic Material

One commercial installation, handling an antibiotic material, has been designed and erected on the basis of an interesting series of pilot-plant and physical studies. The problem involved the dehydrating of the material to less than 0.5% moisture with the drier feed moisture varying between 25 and 40%. This latter range of moistures resulted from the differences in batches and, probably, could not be improved.

At first glance, the product moisture desired would indicate a countercurrent machine, but there were two objections to this choice. First, the material was heat-sensitive and thus a low inlet air temperature would be required to prevent thermal decomposition. Second, the material was dusty, and if countercurrent air were used, a low velocity would be required. Both the low inlet air temperature and low air velocity would increase the required diameter of the machine by 100 to 200 per cent, and lead to more difficult operation. It was decided to investigate the possible use of the Type H unit in order to utilize higher inlet air temperatures and velocities. It was hoped that the baffle and dam structure would permit sufficiently good heat transfer to obtain a product having 0.5% moisture or less, and that these factors would offset the higher efficiencies generally obtained with countercurrent machines. At the time the problem was being studied, the product was being manufactured on a small scale, and was not only in great demand

but also was worth $700 a pound. The request for two drums of material for pilot-plant studies was satisfied with a one-pint sample.

Method of Pilot-Plant Study

The first step in the study of the material was the determination of a drying curve, using both 25 and 40% volatile content samples. For this work the temperature selected was 140° F. which was the approximate temperature the material would discharge from the drier. The antibiotic exhibited a normal drying curve with constant- and falling-rate periods with the slope of the curve at low moistures, falling directly to zero without any bends. The drying rates of the antibiotic in both the constant- and falling-rate period were higher than that of 80-mesh wood flour, which is a material considered easy to dry at least down to 5% moisture.

Although the drying-rate curves showed the antibiotic material to have a high drying rate and no peculiar drying characteristics, it was impossible to tell from this information whether the material could be dehydrated in a parallel-current rotary unit to the low moisture contents desired. At the time the problem was being studied, the small glass Type H unit previously described was available in the pilot plant. The unit was built for exhibition and demonstration, but it was possible to heat the air to the drier electrically to the temperatures desired and the Pyrex shell would stand these temperatures. A photograph of this unit is shown in Figure 4.

Sufficient sample of the material being studied was available for making qualitative tests in the glass unit. The prime purpose of these tests was to determine the exhaust temperature required to obtain, if possible, a product having less than 0.5% moisture. Two tests were conducted at feed rates of 20 and 30 g./min. with inlet air temperatures of 365° F. Results are given in Table 11. They show that at an exhaust temperature of 160° F., a product having the desired moisture content was obtained. The glass shell permitted visual examination of the handling of the material in the drier. The sample tested had a higher moisture content than was to be expected in production (49%), and yet this material handled well in the unit and did not exhibit tendencies to ball or stick.

Although the above tests strongly indicated the required conditions for design of the field unit, it was felt that a verification of the results on a pilot-plant-size machine was desirable. Several materials then available in the laboratory were investigated, and it was found that a batch of benzoic acid exhibited drying rate and physical properties similar to the antibiotic material. Two tests were run with the benzoic acid in the small glass drier, and these results are given in Table 11. Tests showed that benzoic acid would exhibit handling and drier exhaust characteristics similar to those of the antibiotic, so the benzoic acid was selected for testing in the 1-ft. diam. by 8-ft. long pilot-plant unit. After several exploratory runs the test described in Table 11 was conducted, and the results used for design purposes. The glass drier did not have a variable-speed fan and therefore this variable had to be investigated in the pilot-plant unit. The velocity shown in Test No. 5 was found to be about the optimum velocity to give the proper exhaust air temperature and product moisture content. This higher velocity naturally was used in design to reduce as much as possible the diameter of the drier.

Table 9.—Drying of Brewers Grains in Type H Pilot Plant Unit

TEST NO.	FEED RATE LB./HR.	FEED MOISTURE %, WET BASIS	PRODUCT MOISTURE %, WET BASIS	FEED TEMP. ° F.	PROD. TEMP. ° F.	AIR TEMP., ° F. INLET	AIR TEMP., ° F. OUTLET	AIR VEL. FT./MIN.
DRIER SIZE 1 IN. DIAM. × 4 FT. 8 IN. LONG; DAM RINGS 3 IN. APART, BAFFLES CENTERED BETWEEN RINGS								
1	75	67.6	11.1	100	140	1200	196	225
2	90	67.6	9.9	100	150	1200	218	275
3	100	67.6	7.6	100	155	1200	230	330
4	120	70.5	3.9	100	165	1200	294	400
5	105	67.6	7.3	100	150	1600	220	225
6	105	67.6	5.8	100	160	1600	247	275
7	120	67.6	5.4	100	160	1600	270	330
8	165	70.5	6.4	100	170	1600	317	400
DAM RINGS 4 IN. APART; BAFFLES CENTERED BETWEEN RINGS								
9	135	70.3	10.1	90	175	1200	395	450
10	165	70.3	5.8	90	175	1600	395	450
11	120	70.3	9.3	90	165	1200	340	360
12	165	70.3	7.1	90	170	1600	350	360
DRIER SIZE 1 IN. DIAM. × 5 FT. 8 IN. LONG; DAM RINGS 3 IN. APART, BAFFLES CENTERED BETWEEN RINGS								
13	145	69.6	11.3	80	150	1200	224	375
14	180	69.6	14.0	80	160	1600	250	375
DRIER SIZE 1 IN. DIAM. × 6 FT. 8 IN. LONG; DAM RINGS 3 IN. APART, BAFFLES CENTERED BETWEEN RINGS								
15	150	75.3	15.4	80	140	1200	196	350
16	180	75.3	8.0	80	150	1600	220	350
DRIER SIZE 1 FT. DIAM. × 8 FT. LONG								
17	170	70.8	9.3	65	145	1400	222	275
18	120	73.6	7.9	88	190	1200	370	480
19	180	73.6	5.9	88	190	1650	376	480

Table 10.—Pilot-Plant Tests with Various Materials

TEST NUMBER	1	2	3	4	5
Feed, lb./hr.	90	195	90	180	105
Feed, H_2O% wet basis	58.3	57.1	49.7	50.9	36.2
Product H_2O % wet basis	5.5	3.6	12.2	9.7	9.8
Feed temp., ° F.	37	70	70	67	70
Product temp., ° F.	140	170	150	169	155
Inlet air temp., ° F. D.B.	700	1500	1200	1200	975
Outlet air temp., ° F. D.B.	195	286	170	257	215
Outlet air temp., ° F. W.B.	150	158	145	139	138
Air velocity, ft./min.	250	415	210	410	210
Density of feed, lb./cu.ft.	24.9	17.5	25	25	32.5
Density of product, lb./cu.ft.	35.3	12.5	18.5	23	22.5
Slope of drier	0	0	0	0	0
Rev./min. of drier	6	5	8	9	5

Test 1—Pressed penicillin mycelium. 1-ft. × 8-ft. unit.
Test 2—Citrus Fines 1-ft. × 8-ft. unit.
Test 3—Corn Germ. 1-ft. × 4 ft. 8-in. unit. Dam Rings 6 in. apart. Baffles 2 in. behind rings.
Test 4—Corn Germ. 1-ft. × 5 ft. 8-in. unit. First foot void except for lifting flights. Next three feet dam rings 3 in. apart, baffles centered. Last four dam rings 4 in. apart, baffles centered.
Test 5—Gluten Feed 1-ft. × 4 ft. 8-in. unit. Dam rings 6 in. apart, baffles 2 in. behind rings.

Table 11.—Comparative Tests with an Antibiotic and Benzoic Acid

TEST NUMBER	1	2	3	4	5
Material		Antibiotic		Benzoic Acid	
Drier diam., in.	5	5	5	5	12
Drier length, ft.	3	3	3	3	8
Feed rate, lb./hr.	2.64	3.96	3.96	2.64	25
Feed moisture, % wet basis	49	49	33	33	33
Product moisture, % wet basis	0.35	0.46	0.8	0.6	0.3
Feed temp., ° F.	60	60	70	70	70
Product temp., ° F.	100	100	100	100	100
Inlet air temp., ° F.	365	365	315	315	310
Outlet air temp., ° F.	160	152	148	157	165
Air velocity, ft./min.*	150	150	150	150	240
Drier rev./min.	7	7	7	7	5
Retention time, min.	3.5	2.5	4	5	6

* Air velocity determined at exhaust conditions and figured for drier shell diameter of 5 or 12 in.
Tests 1-4 were conducted in small glass shell drier.
Test 5 conducted in 1-ft. × 8-ft. pilot-plant unit.

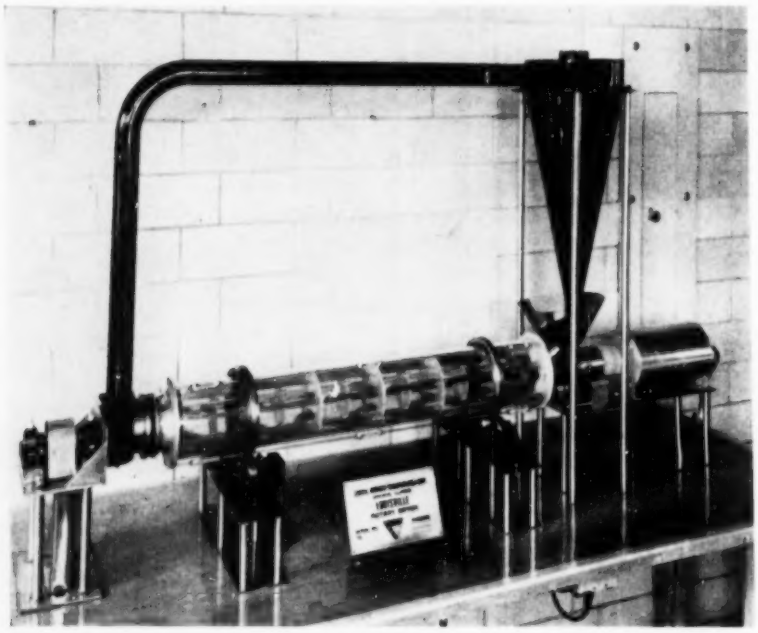


Fig. 4. Glass Type *H* unit.

DESIGN AND OPERATION OF COMMERCIAL UNIT

The commercial unit designed from the above tests is a 48-in. diam. by 25-ft. unit constructed of Type 304 stainless steel. The inlet air temperature varies from 300-320° F., this temperature is controlled to maintain the exhaust air temperature at 160° F. The exhaust gases and material pass from the drier into a Microcollector. The exhaust fan is on the discharge side of the collector, and it handles 3,350 cu.ft./min. at 160° F. which is the equivalent of 265 ft./min. velocity through a 4-ft. diam. shell. In the original design it was hoped to maintain the exhaust air temperature at 170-180° F., but the lower temperature had to be used because of temperature limitation imposed by the bags in the collector. No extensive field data are available, but the drier is handling 330 lb./hr. of feed material at 40% moisture or equivalent quantities at other moisture contents and producing material at 0.3-0.4% water content.

CONCLUSIONS ON PROPER APPLICATIONS OF TYPE H DRIER

This drier, with the internal structure of baffles and dams, shows particular promise for handling fibrous materials where the drier feed has a high moisture content and a product with 5-15% water is desired. The dehydrating action is such that good heat and material transfer are obtained while maintaining the product at a sufficiently low temperature so as not to injure such important constituents as vitamins, proteins, color or taste. For example, the Type H machine is adapted for such materials as brewers grains, penicillin mycelium, citrus fines or pulp, gluten feed and shredded sweet potatoes.

Another field of application is the use of the machine with heat-sensitive materials which require low-product moistures. In such cases a countercurrent warm air drier is usually indicated despite its advantages of low inlet air temperatures and frequently low air velocities. The Type H drier permits the use of a smaller, more easily operated machine by safely utilizing more heat input through higher inlet air temperatures and velocities.

Literature Cited

1. Bill, C. E., U. S. Patent 2,578,166 (Dec. 11, 1951).
2. Corkill, F. W., U. S. Patent 1,898,480 (Feb. 21, 1933).
3. Friedman, S. J., and W. F. Marshall, Jr., *Chem. Eng. Progress*, **45**, 573 (1949).
4. Gutzeit, G., and J. R. Spraul, *Ind. Heating*, p. 892 (May, 1952).
5. Howard, D. L., U. S. Patent 2,341,101 (Feb. 8, 1944).
6. Lissauer, A. W., U. S. Patent 2,096,049 (Oct. 19, 1937).
7. Mangelsdorff, M. F., U. S. Patent 1,299,492 (April 8, 1919).
8. Perry, J. H., "Chemical Engineers' Handbook, Section 13, by W. R. Marshall and S. J. Friedman; McGraw-Hill Book Co., New York (1950).
9. Walker, G. H., British Patent 605,221 (July 19, 1948).

Discussion

Manning Morrill (Dewey & Almy Chemical Co., Cedar Rapids, Ia.): In the lab. work which you have done with the driers, have you made any experiments putting negative pitch in the driers to increase retention time at a given air flow? Did that help get lower moisture outlet in the product?

Dr. G. Gutzeit: Although, in our pilot-plant work, we have used many times a negative slope with conventional driers in order to increase retention time, no such tests have been made with a Type H unit, which is usually run with zero pitch. We definitely feel that no improvement can be expected by using a negative slope in Type H drier operation, because the movement of the material in this machine depends mainly on the air-stream carrying the solids through the narrow spaces between baffles and dams. In other words, while there are lifting flights in the shell, the material becomes periodically airborne in its travel through the drier shell, and the velocity of its advance due to ordinary showering action is negligible compared with the velocity of "blowing through" these narrow zones.

Presented at A.I.Ch.E. Chicago Meeting

ABSTRACTS

*Abstracts of papers published in "Heat Transfer—Atlantic City," Chemical Engineering Progress Symposium Series No. 5, Vol. 49 (1953). The volume may be purchased from Chemical Engineering Progress, 120 East 41 Street, New York 17, New York.**

Temperature and Velocity Distribution in Wake of a Heated Cylinder

V. J. Berry, D. M. Mason, and B. H. Sage
California Institute of Technology

Temperature and velocity traverses were measured at seven positions downstream from a heated cylinder for a series of air speeds up to 90 ft./sec. Values of the thermal transfer from the outside of the cylinder were determined. Results permitted an analysis of thermal and momentum transfer upon which was based a prediction of the velocity and temperature profiles in the wake of a cylinder.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 1 (1953).

Heat Transfer in Air from a Single Tube in a Staggered-Tube Bank

N. W. Snyder
University of California, Berkeley

Ten rows of tubes were employed in this experiment, six in one row and five in the alternate. One tube, electrically heated, could be placed in any position within the bank to measure the local coefficients of heat transfer on the tube. By changing the tube from one position to another, it was possible to get the heat-transfer coefficients for the entire bank under a series of velocities for air flow. Data were correlated by plots in which the Nusselt moduli were functions of the Reynolds moduli to a power.

Chem. Eng. Progress Symposium Series—"Heat Tarnsfer—Atlantic City," **49**, No. 5, 11 (1953).

Natural-Convection Transfer Processes: Heat Transfer to Liquid Metals and Nonmetals at Horizontal Cylinders

Seymour C. Hyman, Charles F. Bonilla, and Stanley W. Ehrlich
Columbia University

Experimental data were obtained on fourteen liquids, including several liquid metals, in natural convection. The apparatus was a horizontal tube electrically heated, the tubes varying in diameter from ¼ to 1½ in.; the surface temperatures on the tube were measured by thermocouple effect between plated layers of nickel and copper, and coefficients of heat transfer were obtained by knowing the electrical input and the temperatures of the liquid and the surface of the tube. Correlation data are shown in general as a plot of the Nusselt number as a function of the Grashof-Prandtl number.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 21 (1953).

Heat-Transfer Coefficients for Liquid Mercury and Dilute Solutions of Sodium in Mercury in Forced Convection

T. C. Doody and A. H. Younger
Purdue University

Heat-transfer measurements were made in a double-pipe exchanger. Liquid metal flowed through a water-jacketed pipe, and the film coefficients between the pipe and the liquid were observed by means of thermocouples in the wall. Coefficients were approximately doubled when small concentrations of sodium were added to mercury. Work was done from room temperature to about 160° F. Correlations of the data are shown in general as Nusselt numbers as a function of the Reynolds number to some power.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 33 (1953).

Performance of Small Liquid-Metal Heat Exchangers

R. A. Tidball
Mine Safety Appliances Company

The flat-plate and shell-and-tube types of heat exchangers were tested in short- and long-term operation. Sodium or sodium potassium alloy was used in the tests, and the temperature level was about 1000° F. Data on flat-plate exchangers agreed with those of Harrison and Menke in a plot of Nusselt vs. Peclet numbers within about 9%. For the shell-and-tube exchanger, there was about a 25% scattering in comparison with Donohue's correlation. Over a period of 75 weeks there was no fouling.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 43 (1953).

Heat Transfer Between Beds of Fluidized Solids and the Walls of the Container

Robert D. Toomey and H. F. Johnstone
University of Illinois

Data are presented for the transfer of heat from a central electric heater to a vertical fluidized bed and thence to the walls of the bed. Use of high-speed photography permitted the treatment of the two-phase unsteady-state system as though it were a steady-state system. Added was the plot of the Nusselt number vs. a product of the Reynolds number and the log of the ratio of the superficial velocity of the fluid to the minimum superficial velocity that is necessary for fluidization—a ratio that embodies a new concept in heat transfer.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 51 (1953).

Design of Heat Exchangers Involving Three Fluids

V. Paschkis and M. P. Heisler
Columbia University

This paper is based on the study of the commercial problem, solved by use of an analogue computer, of predicting the proper design of an exchanger involving air, nitrogen, and oxygen. Calculations gave the length of the exchanger as a function of the temperature of the fluids. The paper discusses generally analogue computations, as well as alternate and analytical methods.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 65 (1953).

Effect of Forced Circulation Rate on Boiling-Heat Transfer and Pressure Drop in a Short Vertical Tube

Joseph L. Schweppe and Alan S. Foust
University of Michigan

Results of boiling film coefficients were measured and reported to streams of boiling water at incipient boiling conditions, in about a 10-in. section of three different diameters. An influence of agitation continued with increasing velocity up to the highest velocity measured, which was approximately 40 ft./sec. Inversion in pressure gradient between 200 and 300 lb./sq.ft. was found at mass velocities and corresponds to an entering liquid velocity of approximately 3 linear ft./sec., beyond which there is a range in which the pressure gradient decreases with increasing velocity. At higher velocities the pressure gradient increases. This phenomenon is explained on the basis of sonic choking at the end of the tube, which results in a suppression of vaporization so that in this

* See advertisement on page 74.

region of inversion, where there is actually a decrease in pressure gradient, there is a corresponding decrease in linear velocity even though the mass velocity is increasing.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 77 (1953).

Two-Phase One-Dimensional Flow Equations and Their Application to Flow in Evaporator Tubes

Bruce F. Harvey and Alan S. Foust
University of Michigan

A mathematical analysis is presented in which equations of state, energy balance, momentum balance, and an equation of continuity are combined into an equation which is solved by a method of isoclines. This gives a relation between the peak temperature attained in a long-tube vertical evaporator and the vapor-head temperature. The mathematical analysis is tested and found accurately applicable to experimental data on a 20-ft.-long 1¼-in.-diam. evaporator tube covering a range of pressures below atmospheric for pure water boiling.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 91 (1953).

Boiling Coefficients Outside Horizontal Tubes

John E. Myers and Donald L. Katz
University of Michigan

Boiling film coefficients for several fluids used as refrigerants are presented for both plain and finned tubes of the low-fin integral type. The boiler used contained four horizontal active tubes in a vertical row, so that the influence of position and behavior of the lower tubes might be accurately measured. Boiling film coefficients were experimentally determined for the plain tubes. For the finned tubes, an analysis was made of the over-all coefficients using a modified Dittus-Boelter-type equation for the water film coefficient on the inside, the water being used as the heating medium. The fluids used were Freon 12, methyl chloride, propane, sulfur dioxide, and normal butane, over part of the range of temperatures and pressures in which they are likely to be used industrially.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 107 (1953).

Solution of a Nonlinear Problem in Transient Heat Conduction Involving Temperature-dependent Thermal Properties

John A. Beutler, Jr., and James G. Knudsen
Oregon State College

This mathematical analysis presents an improvement in accuracy beyond the usually available charts for the Fourier series applicable to steady state in a linear variation of thermal conductivity. The availability of a generalized solution chart in which this variation is recognized should improve the accuracy up to about 10% in the unaccomplished temperature change for solids in which the characteristics of the solid or the temperature range demand recognition of a change in thermal conductivity. The parameters in which this equation yields the results are slightly different from the Fourier-series type.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 115 (1953).

External Heat Exchangers in Unsteady-State Systems

E. P. Lynch
Blaw-Knox Construction Company

The unsteady-state heat transfer encountered when a batch of fluid in a tank—either a constant amount of fluid or a batch to which a constant-rate addition is being made—is circulated has been investigated. Constant conditions in the exchanger were maintained except for the exit temperature of the cooling fluid. The differential equations for the system have been integrated so that by application of the parameters of Bowman, Mueller, and Nagle and the correlation of Ten Broeck, the system may be solved for multipass and crossflow exchangers.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 121 (1953).

Heat Transfer to Slurries in Pipe, Chalk and Water in Turbulent Flow

Charles F. Bonilla, Armando Cervi, Jr., Thomas J. Colven, Jr., and Shih J. Wang
Columbia University

In the selection of physical properties for the slurry in terms of the physical properties of the medium and the suspended material, thermal conductivity was accepted as the conductivity of the medium, water, and specific heat as the weighted additive value for the two constituents. Viscosity was measured by the capillary and concentric-cylinder rotational-viscometer methods and computed by three equations for viscosities of suspensions, those of Einstein, Hatschek, and Kunitz. The Hatschek relation gives the best agreement between different concentrations at Reynolds numbers above 100,000. An empirical correction for the effect of concentration down to a Reynolds number of 10,000 was also developed.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 127 (1953).

Heat-Transfer Coefficients in Liquid Mixing Using Vertical-Tube Baffles

I. R. Dunlap, Jr., and J. H. Rushton
Illinois Institute of Technology

This problem is the influence of various sizes and arrangements of rotors as agitators heating a batch of fluid in a tank in which the baffles are heat sources or heat sinks, being pipes arranged on the periphery of the tank in various numbers. Two different systems geometrically similar and almost identical were studied, with various agitators, using both heat source and heat sink to the batch of fluid. The correlation was determined using a Nusselt number related to the baffle-tube diameter, this being expressed in terms of an agitator Reynolds number which is a velocity and a dimension term related to the agitator, the usual Prandtl number.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 137 (1953).

Thermal Conductivity and Prandtl Number of Air at High Temperatures

Irvin Glassman and Charles F. Bonilla
The Johns Hopkins University

Extrapolation of commonly accepted physical properties usually results in large uncertainties at temperatures much above the experimental range. A survey was made of available experimental data and of theoretical extrapolation procedures and correlation methods. In addition, the range of experimental thermal conductivities for air was extended in a conductivity cell carefully designed to minimize uncertainties of absorption, emissivity, and dimensions of the equipment.

Chem. Eng. Progress Symposium Series—"Heat Transfer—Atlantic City," **49**, No. 5, 153 (1953).

Technical Comment on "Evaporation from Drops"

I am interested in the work of Ranz and Marshall which you published last year (*2*). I should like to offer some of my own findings, made preliminary to embarking on similar experiments, which the work of Dr. Ranz and Dr. Marshall has spared me.

In measurement of drop temperature the effect of the thin wires used to suspend the thermocouples in the drop fluid is negligible. Heat transfer by thermocouple wire to the weld point of the thermocouple, however, affects the accurate measuring of temperature. Thermocouple wires, of constantan and manganin, pass through the hot-gas stream and through the boundary layer around the drop into the center of the drop. Different temperatures and heat rates therefore act on the wires. The diameter of the wires also influences the accuracy of measurement.

Figure 1 gives the temperature picture of the wire when the drop-center temperature t' is above or below (dashed line) the temperature ϑ_e of the drop surface. ϑ_g is the temperature of the gas (air) and practically the temperature of the wire in the gas stream; ϑ_l the temperature of the wire in the drop $= \vartheta_L$ for $l = L$.

With

$$K = \sqrt{\frac{4h}{k \cdot d}} \cdot l \qquad (1)$$

where

h = coefficient of heat transfer from wire in drop (B.t.u./(hr.)(sq. ft.)(° F.)

k = thermal conductivity of the thermocouple wire (B.t.u./(hr.)(sq. ft.)(° F./in.)

d = diameter of wire (in.)

l = length of wire in drop (in.)

we have without any free convection in the drop (corresponding to many solutions) along the dashed line

$$\frac{\vartheta_l}{\vartheta_c} = \frac{1}{\cosh K} \qquad (2)$$

temperature of wire ϑ ° F.	32	68	212
conductivity of constantan k B.t.u./(hr.)(sq.ft.)(° F./in.)	153.9	157.2	177.3
conductivity of manganin k B.t.u./(hr.)(sq.ft.)(° F./in.)	145.2	151.6	183.0

Using the preceding table we may calculate a mean value $k = 162$. Corresponding to a drop diameter $D = 0.03937$ in. $= 10^{-3}$ m, a wire length in drop $l = L = D/2 = 0.01969$ in. $= 0.5 \times 10^{-3}$ m and a wire diameter $d = 0.003937$ in. $= 10^{-4}$ m, we have then corresponding to (1)

$$K = \sqrt{\frac{4}{k \cdot d}} \cdot l\sqrt{h} = \sqrt{\frac{4}{162 \cdot 0.003937}} \cdot 0.01969\sqrt{h} = 0.0493\sqrt{h}$$

With various values of h, we find the following values of ϑ_L/ϑ_c:

h B.t.u./(hr.)(sq.ft.)(° F.) =	0.20482	2.0482	20.482	204.82
10^3 K =	22.3	71	223	710
cosh K =	1.00026	1.00252	1.02283	1.26282
ϑ_L/ϑ_c =	1	1	0.975	0.792

We cannot expect $h > 20.482$, which means $\vartheta_L \approx \vartheta_c$. So we record with our thermocouple in the center the temperature of the drop surface and not that of the drop center. Therefore, no temperature difference results, if we move the weld point of the thermocouple from the drop center to the drop surface.

If we evaporate pure water drops, we must heat or cool all spherical layers of the drop to the wet-bulb temperature t_f during the existence of the drop. For heat balances we can accept $\vartheta_L = \vartheta_c = t_f$ during the full drying time.

The length of wire, both constantan and manganin, in the boundary layer $D/2$, if not moistened, will correspond to $Nu = 2$ so that we have with $d = 0.003937$ in. and thermal conductivity of vapor $k_v = 0.1677$ B.t.u./(hr.)(sq.ft.)(° F./in.) a heat-transfer coefficient from vapor in the boundary layer to wire $h_v = 85.2$ B.t.u./(hr.)(sq.ft.)(° F.). We may expect that h_v will be much greater than h in the drop and h_g as coefficient from gas (air) to wire.

If the wire is moistened in the boundary layer, we can assume that wire surface and therefore inner temperature of the wire $= t_f$ up to gas temperatures t_g of about 212° F. The thinner the wire, the greater K and the lower ϑ_L/ϑ_c, but not much less than 1. When the drop is hanging freely from a burette, we may insert thin thermocouple wires through the burette bore into the center of the drop and thus measure true center temperature. But we cannot obtain surface temperature this way.

I have distributed a number of thermocouples in a spray tower in such a manner that the drops passing with the air stream moistened the wires and finally formed a drop on the weld point which was periodically thrown off by the air stream. The thermocouples give the wet-bulb temperature at every position. Obviously this temperature is not the center temperature of a normal drying water drop but the surface temperature on the moistened wire, which was covered by the drop-forming fluid.

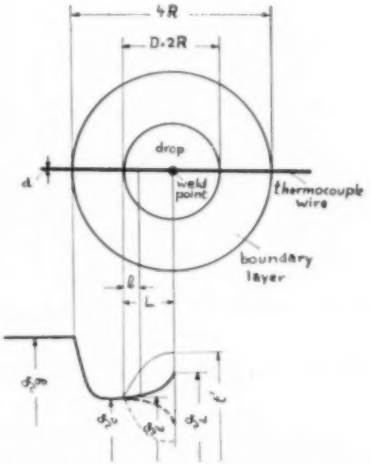


Fig. 1. Temperature picture of thermocouple wire along the boundary layer and in the drop compared with the gas and drop temperature.

Temperature variation on the drop surface can be determined in two ways:

1. If the liquid temperature of the spray $t' > t_f$, we find $t' \to t_f$ in cases where $t_g \leq t'$ from heat- and mass-transfer balance corresponding to Nusselt or Colburn-Drew or Ackermann. It means that the temperatures of all concentric layers of the drop tend to go to t_f on the surface, so that in the balance the full drop volume gets the temperature t_f.

2. If $t' < t_f$, the heating time τ causes the surface temperature t' to rise $\to t_f$ according to the theory of heating a sphere by outside gas stream if there is not free convection in the drop. If a water-sugar drop in dry air ($t_g = 194°$ F.), for example, is to be heated from $t_g = 59°$ F. to $t' = t_f = 86°$ F., with $Re \to 0$, we have $Nu = 2 \approx Nu'$ and the heating time (surface) with

$D = 0.07874$ in.	τ (sec.) $= 0.25 \times 10^{-4}$
$= 0.007874$ in.	$= 0.25 \times 10^{-5}$
$= 0.0007874$ in.	$= 0.25 \times 10^{-7}$

The drop-center temperature remains at $t' = 59°$ F., as inserting thermocouple wires through the burette into the drop center should confirm.

The drop temperature, in conclusion, is determined by the temperature conductivity $a' = k'/\rho' \cdot c'$ of the drop fluid, which is a great deal lower than analogous a_g of gas and air. Therefore, we cannot expect a uniform drop temperature if there is not free convection in the drop. If you gather drops in a number of little glazed jars with a thermocouple inside, you find a mixed temperature of the drop fluid t' which keeps within the bounds of the feed temperature and the wet-bulb temperature, but approaches the latter at a rate in proportion to that at which the drop is moving from the nozzle.

My present statement, of course, does not impair the heat- and mass-transfer, which in this case agrees well with the data of Froessling (*1*).

Literature Cited

1. Froessling, N., *Gerlands Beitraege Geophysik*, **52**, 170 (1938).

2. Ranz, W. E., and Marshall, W. R., Jr., *Chem. Eng. Progress*, **48**, 141, 173 (1952).

H. Tonn

Technische. Universität, Berlin-Charlottenburg

PLASTICS EQUIPMENT REFERENCE SHEET

RAYMOND B. SEYMOUR and ROBERT H. STEINER
The Atlas Mineral Products Co., Mertztown, Pa.

HIGH STYRENE-BUTADIENE COPOLYMER COATINGS: Resins, in which styrene is the major component, are available as solvent-based protective coatings and emulsion-type paints.

APPLICATION AND REMARKS: Protective coatings based on high styrene-butadiene copolymers can be brush, spray or roll-applied to properly prepared metallic and masonry surfaces. No prime coat is required in general but special corrosion-inhibiting primers are recommended for non-sand-blasted steel surfaces. These coatings are especially useful for general maintenance and for decoration of steel and masonry surfaces such as brick, concrete, plaster and asbestos-cement compositions. Special formulations must be used when the coatings are exposed to outdoor weathering conditions. A minimum of three coats is recommended for protection against fumes, vapors or occasional splash and spillage of corrosive materials. Thin organic coatings are not recommended for continuous immersion in corrosive media but may be used to prevent metallic contamination of noncorrosive liquids. Since these coatings tend to retain traces of residual solvent after application, heating of the applied coating at a temperature of about 200° F. for a short period of time or a waiting period of several days at room temperature is recommended before placing these coatings in service under severe corrosive conditions.

CHEMICAL COMPOSITION: These copolymers which contain from 60-90% styrene and 10-40% butadiene are compounded with small amounts of a chemically resistant plasticizer such as chlorinated paraffin and a drying oil. Comparatively large amounts of inert fillers and pigments are also included in the standard compounding formulations. Blends of liquid aromatic and aliphatic hydrocarbons are usually used as solvents for these coatings. While water-emulsion coatings are used widely for interior decorative purposes, the high permeability of the films that are deposited from the emulsion preclude the use of such materials as chemical-resistant finishes. Data given below are for a typical styrene-butadiene protective coating especially formulated for maximum corrosion resistance.

TEMPERATURE LIMITATIONS: Because of the thermoplasticity of styrene-butadiene resins, they are not recommended for use above 150° F.

A TYPICAL STYRENE-BUTADIENE COPOLYMER COATING

PHYSICAL PROPERTIES

Specific gravity	1.05
Water absorption %	0.4
Impact resistance	Excellent
Flexibility	Excellent
Weather resistance	Fair
Abrasion resistance	Good

CORROSION RESISTANCE

	C	H
ACIDS		
Acetic, 10%	F	P
Acetic, glacial	N	N
Benzene sulfonic, 10%	E	E
Benzoic	E	E
Boric	E	E
Butyric, 100%	N	N
Chloroacetic, 10%	N	N
Chromic, 10%	G	N
Chromic, 50%	P	N
Citric	E	E
Fatty acids	E	E
Fluosilicic	E	E
Formic, 90%	N	P
Hydrobromic	E	G
Hydrochloric	E	G
Hydrocyanic	E	G
Hydrofluoric	E	G
Hypochlorous	E	F
Lactic	E	G
Maleic, 25%	E	E
Nitric, 5%	G	P
Nitric, 20%	F	N
Nitric, 40%	N	N
Oleic	E	E
Oxalic	E	E
Perchloric	E	F
Phosphoric	E	G
Picric	E	E
Stearic	E	E
Sulfuric, 50%	E	E
Sulfuric, 70%	G	N
Sulfuric, 93%	N	N
Oleum	N	N
Mixed acids, 52% H_2SO_4 28% HNO_3	N	N
ALKALIES		
Ammonium hydroxide	E	E
Calcium hydroxide	E	E
Potassium hydroxide	E	E
Sodium hydroxide	E	E
ACID SALTS		
Alum or aluminum sulfate	E	E
Ammonium chloride, nitrate, sulfate	E	E
Copper chloride, nitrate, sulfate	E	E
Ferric chloride, nitrate, sulfate	E	E
Nickel chloride, nitrate, sulfate	E	E
Stannic chloride	E	E
Zinc chloride, nitrate, sulfate	E	E
ALKALINE SALTS		
Barium sulfide	E	E
Sodium bicarbonate	E	E
Sodium carbonate	E	E
Sodium sulfide	E	E
Trisodium phosphate	E	E
NEUTRAL SALTS		
Calcium chloride, nitrate, sulfate	E	E
Magnesium chloride, nitrate, sulfate	E	E
Potassium chloride, nitrate, sulfate	E	E
Sodium chloride, nitrate, sulfate	E	E
GASES		
Chlorine, dry	G	N
Chlorine, wet	P	N
Sulfur dioxide, dry	E	E
Sulfur dioxide, wet	E	E
Hydrogen sulfide	E	E
ORGANIC MATERIALS		
Acetone	N	N
Alcohol, methyl, ethyl	E	E
Aniline	N	N
Benzene	N	N
Carbon tetrachloride	N	N
Chloroform	N	N
Ethyl acetate	N	N
Ethylene chloride	N	N
Formaldehyde, 37%	E	E
Gasoline	N	N
Phenol, 5%	E	G
Refinery crudes	N	N
Trichloroethylene	N	N
PAPER MILL APPLICATIONS		
Kraft liquor	E	E
Black liquor	E	E
Green liquor	E	E
White liquor	E	E
Sulfite liquor	E	E
Chlorite bleach	G	F
Alum	E	E
PHOTOGRAPHIC INDUSTRY		
Developers	E	E
General use	E	E
Silver nitrate	E	E
FERTILIZER INDUSTRY		
General use	E	E
STEEL INDUSTRY		
Sulfuric acid pickling	E	E
Hydrochloric acid pickling	E	E
H_2SO_4-HNO_3 acid pickling	F	P
TEXTILE INDUSTRY		
General use	E	E
Hypochlorite bleach	G	F
FOOD INDUSTRY		
General use	E	E
Breweries	E	E
Dairies	E	E
MISCELLANEOUS INDUSTRIES		
Plating	E	E
Petroleum	N	N
Tanning	E	E
Oil and soap	E	E
Water and sewer	E	E

RATINGS:

E—No attack.
G—Appreciably no attack.
F—Some attack but usable in some instances.
P—Attacked—not recommended.
N—Rapidly attacked.
C—Cold—75° F.
H—Hot—150° F. or boiling point of test solution.

No. 23

The Professional Earnings and Career Satisfaction of A. I. Ch. E. Members

Results of the National Survey Questionnaire

J. A. Polack, G. E. Montes, and L. B. Smith Baton Rouge, La.

Members of the Questionnaire Subcommittee from the Baton Rouge Section responsible for the design, study, and analysis of the A.I.Ch.E. Questionnaire: Lloyd B. Smith, chairman; J. A. Polack; and G. E. Montes.

The present article, a follow-up on the initial report on the A.I.Ch.E. national survey questionnaire which appeared in the April issue (*2*), presents correlations on questions dealing with professional income, college training, experience, and job satisfaction. As pointed out in the earlier article, 64.4% of the questionnaires sent out, or almost 8,000 out of 12,000, were returned; and the present results are therefore based on what would seem to be a good sample of A.I.Ch.E. membership.

The earning power of chemical engineers is certainly a matter of interest to all of us. As will be seen from the results, income of A.I.Ch.E. members varies appreciably between low and high, with individual performance apparently the determinng factor. Neither college degree nor company size appears to have much effect. Some differences are shown for field of endeavor, as might be expected; e.g., the management group has a higher than average income.

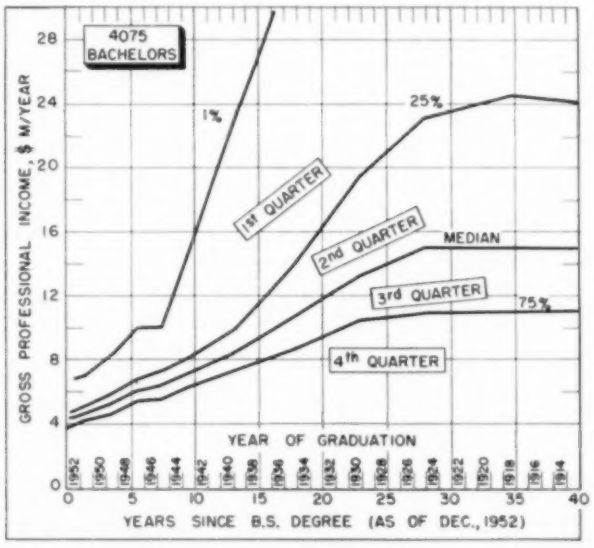


Fig. 1.

Limitations of the Data

In interpreting the survey results, it is well to bear certain precautions in mind. Primarily, one should remember that the information applies specifically to those 7,802 members who filled in the questionnaire and must not necessarily be assumed to apply to others. The A.I.Ch.E. membership is in itself a selected group. In addition, no distinction has been made, in calculating the average salaries, between supervisory and non-supervisory personnel. For this reason, the income levels for the present survey may be expected to be somewhat higher than those shown by other surveys in which supervisory people were intentionally excluded (*1*). Another factor which could influence the interpretation of the data is that those members who chose not to answer the salary question might be concentrated in a particular group. For example, a rather high percentage of "no answers" came from the older men in small companies.† They could constitute either an overpaid or an underpaid group, and omitting them, as must be done, could bias the results. Finally, it should be emphasized that these data represent the situation as of December, 1952, *only*. No information on incomes of other years is presented. The reader may be interested in comparing these national results with the results of the Regional survey reported last August (*3*).

Results

General Observations.

The annual professional incomes of the respondents to the questionnaire are presented in detail in Table 1 and are plotted in Figures 1, 2 and 3. Data are given for finite intervals of salary and years. For plotting the curves, the midpoint of the time interval was used, and

† About 5% of the members in companies having less than ten technical employees checked "no answer"; and 14% in the small-company group having more than thirty years' experience also checked "no answer."

median income, etc., was calculated using linear interpolation within the salary interval.‡ This procedure is not quite so rigorous as smoothing the distribution data on a probability plot, but it is much less tedious and should be satisfactory for the present purposes. The "Quarters" shown in Figures 1, 2 and 3 merely serve to divide the members into four groups, each group containing the same number of individuals. The percentages shown on the various curves represent the per cent of members having incomes *greater* than the curves involved. The 1% line serves only to approximate the top of the distribution in each case, and should not be considered too exact since in small groups, 1% may represent only a fraction of an individual. Totals may differ in the various correlations. This results from failure on the part of individuals to answer every question properly.

Of primary interest to the individual is how he compares with classmates of equivalent training. The individual can best make this comparison by reference to Table 1. Suppose one holds a bachelor's degree granted eighteen years ago, and has made $15,000 in 1952. By referring to Part B of Table 1, he will note that 420 A.I.Ch.E. members (replying to the questionnaire) have approximately the same years' experience and training as himself, but only about seventy-two, or 17% have higher income. Reference to Part C of the table would show that 275 of his classmates stayed at school to obtain a master's degree, and about forty-one of these attained a higher professional income. Such an individual may place the amount of his professional income as a datum point on the curves of Figure 1, and for the example given he will locate his position in the top quarter.

Let us consider next the earnings of the profession as a whole. Figure 1 is typical and will be used for discussion. It will be noted from the Figure that 50% of the bachelor's degree holders, who graduated twenty years ago, earned more than $1000 a month in 1952. Three fourths of them earned more than about $800 a month. This group, graduated during the depression, would average about forty years of age. Those who graduated thirty years ago have a median professional income of $15,000 a year, with 25% reaching above $24,000 a year or $2,000 a month.

Median salary increases steadily with years of experience. At any given year, however, there is a tremendous spread from low to high. Thus, while age or years of experience is a factor, it appears that individual performance is of primary importance.

It should be remembered that these curves are not growth curves, but present the income distribution only at the end of 1952. They are flatter than growth

(*A.I.Ch.E. Survey Continued on page 20*)

‡ As an example, consider Bachelors in the 11-15 year group (Table I, Part B). There were 958 individuals in this group, of which 954 answered the questions appropriately. The top 25% would include $954/4 = 238.5$, say 239 members. Examination of the table will show that the 239th member falls in the salary interval $9001-10,000. Since $174 + 27 + 3 + 1 = 205$ members were above $10,000, $239 - 205 = 34$ members in the top quarter would have incomes between $9000 and $10,000. To find the 25% point (or income of the 239th member) linear distribution within the salary interval was assumed. Thus, the salary at the 25% point would be $10,000 - 34/155\ (1000) = \$9,780$, which is plotted at thirteen years (Fig. 1). Therefore, as the curve shows, 25% of the Bachelors in the 11-15 year group have incomes greater than $9,780/year.

Table 1.—Annual Professional Income of A.I.Ch.E. Members

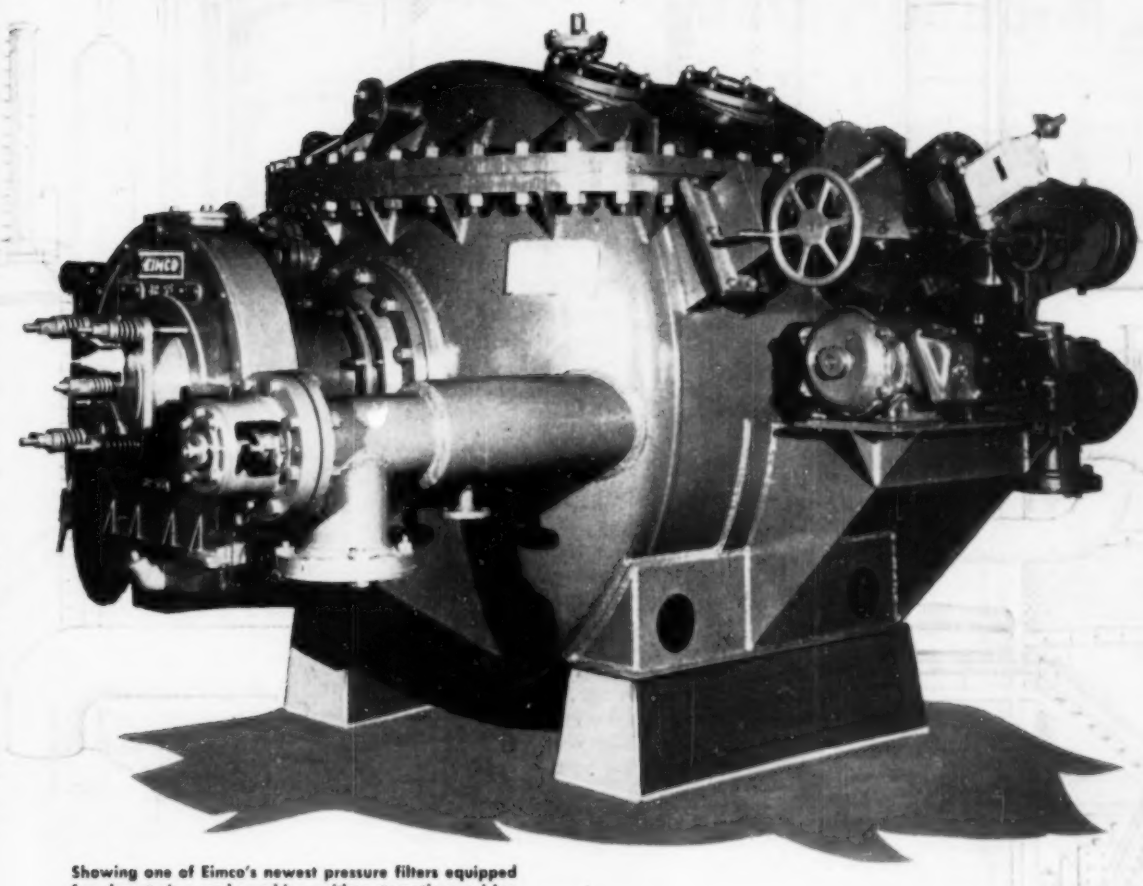
Part A: MEMBERS HOLDING NO COLLEGE DEGREE

Number of Members Having Indicated Annual Professional Income

$/Yr.	Less Than 4,000	4,001–5,000	5,001–6,000	6,001–7,000	7,001–8,000	8,001–9,000	9,001–10,000	10,001–15,000	15,001–25,000	25,001–50,000	More Than 50,000	No Answer	IBM Rejects	Total
Years in Profession														
< 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 or 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 or 4	0	0	0	0	0	0	0	1	0	0	0	0	0	1
5 or 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 or 8	0	0	1	0	0	0	0	0	0	0	0	0	0	1
9 or 10	0	0	1	0	0	1	0	0	0	0	0	0	0	2
11–15	0	0	0	1	2	0	2	3	0	0	0	0	0	8
16–20	0	0	0	0	3	1	1	5	1	0	0	0	0	11
21–25	0	0	0	0	1	1	0	6	3	0	0	1	0	12
26–30	0	0	1	0	0	1	1	4	2	0	0	0	0	9
31–40	0	0	0	0	0	1	0	4	4	2	1	0	1	13
40	0	0	0	0	0	1	0	1	2	0	0	0	0	4
Rejects	0	0	0	1	2	0	3	2	0	3	0	1	0	12
Total	0	0	3	2	8	6	7	26	12	5	1	2	1	73
Part B:														
Years Since B.S. Degree	MEMBERS HOLDING BACHELOR'S DEGREE (or equivalent)													
< 1	32	74	8	1	1	0	0	1	0	0	0	8	0	125
1 or 2	43	261	94	4	2	2	0	2	0	0	0	6	2	416
3 or 4	22	175	244	62	17	4	3	0	0	0	0	4	0	531
5 or 6	1	23	128	125	39	11	8	2	1	0	0	4	0	342
7 or 8	4	10	51	56	35	13	5	2	0	0	0	2	0	178
9 or 10	1	21	95	187	188	106	28	36	3	0	0	5	1	671
11–15	3	6	45	136	210	194	155	174	27	3	1	3	1	958
16–20	0	0	5	17	43	53	61	162	60	11	1	4	3	420
21–25	0	0	2	4	3	16	13	78	42	16	3	2	1	180
26–30	0	0	2	4	4	6	8	38	39	19	2	2	1	125
31–40	1	0	1	1	7	4	16	41	37	26	4	4	0	142
> 40	3	0	2	1	0	1	0	11	10	8	0	5	2	43
Rejects	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Total	110	570	677	598	549	410	297	548	219	83	11	49	8	4132

Table 1 (*Continued on page 20*)

CONTINUOUS PRESSURE FILTERS



Showing one of Eimco's newest pressure filters equipped for dewatering and washing with automatic precision scraper blade advancing mechanisms.

Every Eimco Filter for vacuum or pressure operation, or combination of the two, is a custom built machine designed and constructed to meet the specific requirements of your process.

The machine pictured above is another typical example of Eimco custom built filter design. This filter is part of the flow sheet in a plant producing phenol, acetone and alphamethyl styrene. The purpose of the filter is to remove sodium sulphate crystals and small amounts of water and it was also necessary that the phenol in precoat cake be reduced to .05% washing with crude acetone and separating the strong and weak filtrates.

Eimco's testing and development departments are staffed with experienced chemical and metallurgical engineers whose work with consulting engineering firms and the engineering departments of many producing companies has resulted in economies in operation and production of their product.

May we have an opportunity to consult with you and quote on your filter requirements?

EIMCO 1458

THE EIMCO CORPORATION

The World's Leading Manufacturer of Vacuum Filtration Equipment

EXECUTIVE OFFICES AND FACTORIES · SALT LAKE CITY 10, UTAH, U. S. A.

BRANCH SALES AND SERVICE OFFICES:

NEW YORK, 51-52 SOUTH STREET • CHICAGO, 3319 SOUTH WALLACE STREET
BIRMINGHAM, ALA., 3140 FAYETTE AVE • DULUTH, MINN., 216 E SUPERIOR ST.
EL PASO, TEXAS, MILLS BUILDING • BERKELEY, CALIF., 637 CEDAR STREET
KELLOGG, IDAHO, 307 DIVISION ST. • LONDON W. 1, ENGLAND, 190 PICCADILLY

IN FRANCE, SOCIETE EIMCO, PARIS, FRANCE
IN ENGLAND, EIMCO (GREAT BRITAIN) LTD., LEEDS 12, ENGLAND
IN ITALY, EIMCO ITALIA, S.P.A., MILAN, ITALY

Table 1.—(*Continued from page 18*)

Part C:

MEMBERS HOLDING MASTER'S DEGREE (or equivalent)

Number of Members Having Indicated Annual Professional Income

$/Yr.	Less Than 4,000	4,001–5,000	5,001–6,000	6,001–7,000	7,001–8,000	8,001–9,000	9,001–10,000	10,001–15,000	15,001–25,000	25,001–50,000	More Than 50,000	No Answer	IBM Rejects	Total
Years Since B.S. Degree														
< 1	2	4	1	0	0	0	0	0	0	0	0	0	0	7
1 or 2	10	26	47	2	0	0	0	0	0	0	0	3	1	89
3 or 4	22	49	158	39	9	1	1	1	0	0	0	3	1	284
5 or 6	7	10	79	71	26	5	3	5	0	0	0	0	0	206
7 or 8	3	5	42	63	38	13	3	3	0	0	0	7	0	177
9 or 10	3	10	46	107	81	41	29	15	2	0	0	5	0	339
11–15	1	2	15	58	108	116	89	148	14	4	0	9	0	564
16–20	1	0	4	20	29	31	40	107	36	5	0	2	0	275
21–25	1	1	3	8	7	10	21	48	32	14	1	4	0	150
26–30	1	1	1	0	6	5	9	28	24	12	3	2	0	92
31–40	0	0	2	1	6	6	5	19	18	21	2	4	1	85
> 40	0	0	1	1	1	1	3	5	5	3	2	5	1	28
Rejects	0	0	0	0	1	0	0	1	0	0	0	0	0	2
Total	50	108	399	370	312	229	203	380	131	59	8	44	4	2298

Part D:

MEMBERS HOLDING DDCTOR'S DEGREE (or equivalent)

Years Since B.S. Degree														
< 1	0	0	0	1	0	0	0	0	0	0	0	1	0	2
1 or 2	0	0	0	4	1	1	0	0	0	0	0	1	0	7
3 or 4	3	0	3	13	2	2	0	0	0	0	0	4	0	27
5 or 6	0	0	8	27	23	5	1	0	0	0	0	1	0	65
7 or 8	2	0	6	35	40	2	3	2	0	0	0	0	0	90
9 or 10	2	0	13	34	46	31	13	10	0	0	0	4	0	153
11–15	1	2	11	28	54	62	43	83	10	2	0	2	1	299
16–20	0	0	3	3	11	22	29	77	30	9	0	3	0	187
21–25	0	0	1	8	9	9	19	65	42	11	2	7	0	173
26–30	0	0	1	6	7	6	7	31	29	11	4	4	0	106
31–40	0	0	3	3	4	5	7	17	15	24	3	6	0	87
> 40	3	0	1	0	2	3	2	6	8	2	3	2	0	32
Rejects	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Total	11	2	50	162	199	148	124	291	135	59	12	35	1	1229

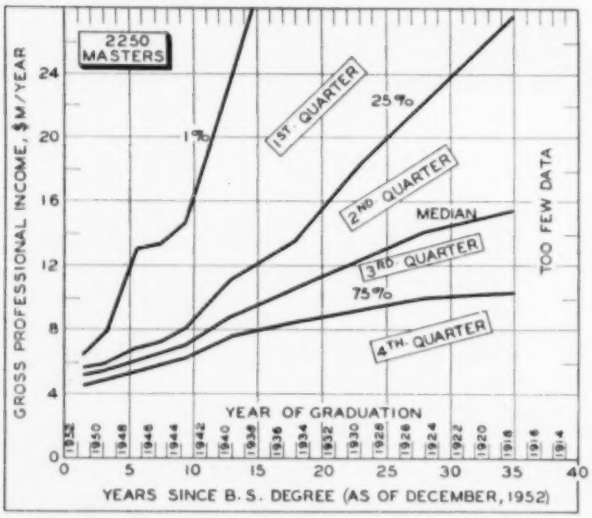


Fig. 2.

Table 2.—Effect of Company Size on Income of A.I.Ch.E. Members

Number of Technical Employees	< 10	10–100	101–1,000	> 1,000
	MEDIAN INCOME, $/YR.			
YEARS SINCE B.S. DEGREE				
1 or 2	4,700	4,600	4,700	4,700
5– 6	6,600	6,200	6,100	6,300
11–15	10,000	8,500	8,400	8,700
21–25	12,500	12,100	12,800	13,500
31–40	16,100	16,200	13,800	17,500
	INCOME AT UPPER 25% LEVEL, $/YR.			
1 or 2	5,500	5,200	5,200	5,300
5 or 6	8,400	6,900	6,900	6,900
11–15	13,500	10,700	9,900	10,100
21–25	21,700	17,100	18,900	17,500
31–40	22,200	28,300	25,000	26,500
Total No. of Usable Responses	455	1,139	3,031	2,933

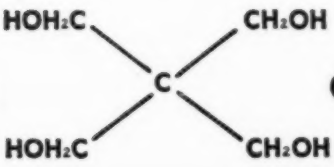
curves because the left-hand end is forced upward by the high current starting salaries. Individuals with ten or more years' experience, who started at $125 or less a month, will quickly see that their own growth curves are steeper than these distribution curves.

Effect of Degree

A glance at Figures 1, 2 and 3 will suffice to show that there are no significant differences in the income distribution among PhD.'s, M.S.'s, and B.S.'s. (There are too few members having no degree to plot curves for this group.) The Ph.D's have a higher starting salary, as is well known, but this advantage is minimized after about ten years. The median Ph.D. does enjoy about a $50 a month advantage over his median B.S.

(*Continued on page 22*)

HERCULES



keeps quality uniform

...with FOXBORO Control

From the scale to the drier, Hercules Pentaerythritol is produced under "automatic" process control that makes uniform batches of this important Alkyd Resins Intermediate a certainty. At every stage of the process, Foxboro Controllers automatically hold temperature, pressure, and flow of reactants exactly as pre-set by the operator. And when production rates are reset, Foxboro control action swings smoothly, instantly to the new control points.

A wide variety of processes throughout the chemical industry are being successfully controlled by Foxboro Instruments. Whether your production problem involves temperature, pressure, flow or other process variables, Foxboro Control can help you get better product quality . . . efficiently. Write for engineering data covering your particular problem.

A few of the 25 Foxboro Instruments that automatically control the pentaerythritol process at Hercules Powder Company's Mansfield, Mass. plant. Operator can instantly change production rates at any stage.

FOXBORO REG U S PAT OFF **INSTRUMENTATION**

THE FOXBORO COMPANY, 937 NEPONSET AVE., FOXBORO, MASS., U.S.A. • FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

Table 3.—Effect of Type of Work on Income of A.I.Ch.E. Members

MEDIAN INCOME, $/YR.*

Years Since B.S.	Res. & Dev.	Design	Operation	Teaching	Consulting	Sales	Management
1 or 2	4,650	4,650	5,000	**	**	4,650	**
5–6	6,100	6,200	6,100	5,650**	**	6,150	7,000
11–15	8,150	8,550	8,700	7,850	9,650	8,900	11,100
21–25	12,900	11,300	12,000	9,850	12,850**	12,700	17,350
31–40	13,900	10,400**	11,650	9,400**	18,150	16,900	25,250

INCOME AT UPPER 25% LEVEL, $/YR.*

Years Since B.S.							
1 or 2	5,100	5,150	5,850	**	**	4,900	**
5–6	6,850	6,800	7,000	7,400**	**	6,950	8,500
11–15	9,600	9,750	9,850	9,300	12,950	10,750	13,950
21–25	18,050	15,000	14,650	13,150	15,000**	18,750	24,300
31–40	22,100	14,000**	14,850	12,300**	32,000	21,600	37,000
Total No. of Usable Responses	2,449	1,135	1,786	358	178	384	838

* To nearest $50. ** Few or insufficient data.

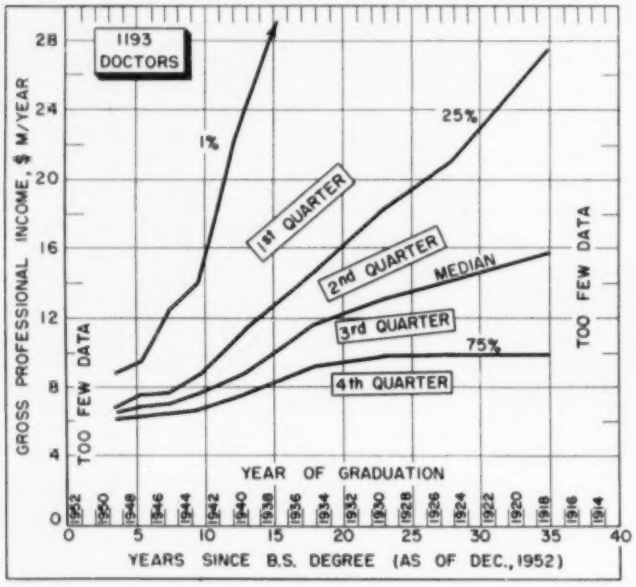


Fig. 3.

Table 4.—Career Satisfaction

Do you feel you made correct choice of career in becoming a Chemical Engineer? → / Does your employer recognize you as a professional man? ↓	Yes	No	Undecided	Total	
Yes	5,566	293	589	6,448	
% of Total	75	3.9	7.8		86.7
No	319	73	89	481	
% of Total	4.2	1.0	1.2		6.4
Undecided	362	47	101	510	
% of Total	4.9	0.6	1.4		6.9
Total	6,247	413	779	7,439	
% of Total	84.1	5.5	10.4		100

and M.S. contemporaries in the 10-20-year period, but this difference would appear less significant than the obvious overlap in distribution. Thus, the charts indicate that while the median Ph.D., fifteen years after getting his bachelor's degree, earns $10,000 a year, the median bachelor sixteen years out attains the same income.

It seems safe to conclude that the important factor is clearly not the college degree: the wide salary spread is the same, regardless of degree. Age, and more important, individual performance or other individual factors determine income.

Effect of Company Size

A commonly heard opinion is that employees of small organizations have higher incomes than those of large. Data on this question presented in Table 2 support this impression only in part. First, it is quite evident that there are no significant income differences for all company sizes involving more than ten technical employees. Second, if one considers median incomes, practically no effect of company size is apparent at all. The main distinction of the small company (fewer than ten technical employees) seems to be that the top incomes are achieved sooner. Those falling into the 25% bracket in the small companies have a small advantage over the same group in larger companies. Nevertheless, even this advantage appears to be lost after about twenty-five years, as shown in the following brief summary:

	% Above $15,000/Year	
No. Technical Employees	<10	>1000
Years since B. S.		
11-15	14%	2.5%
26-30	47%	49%

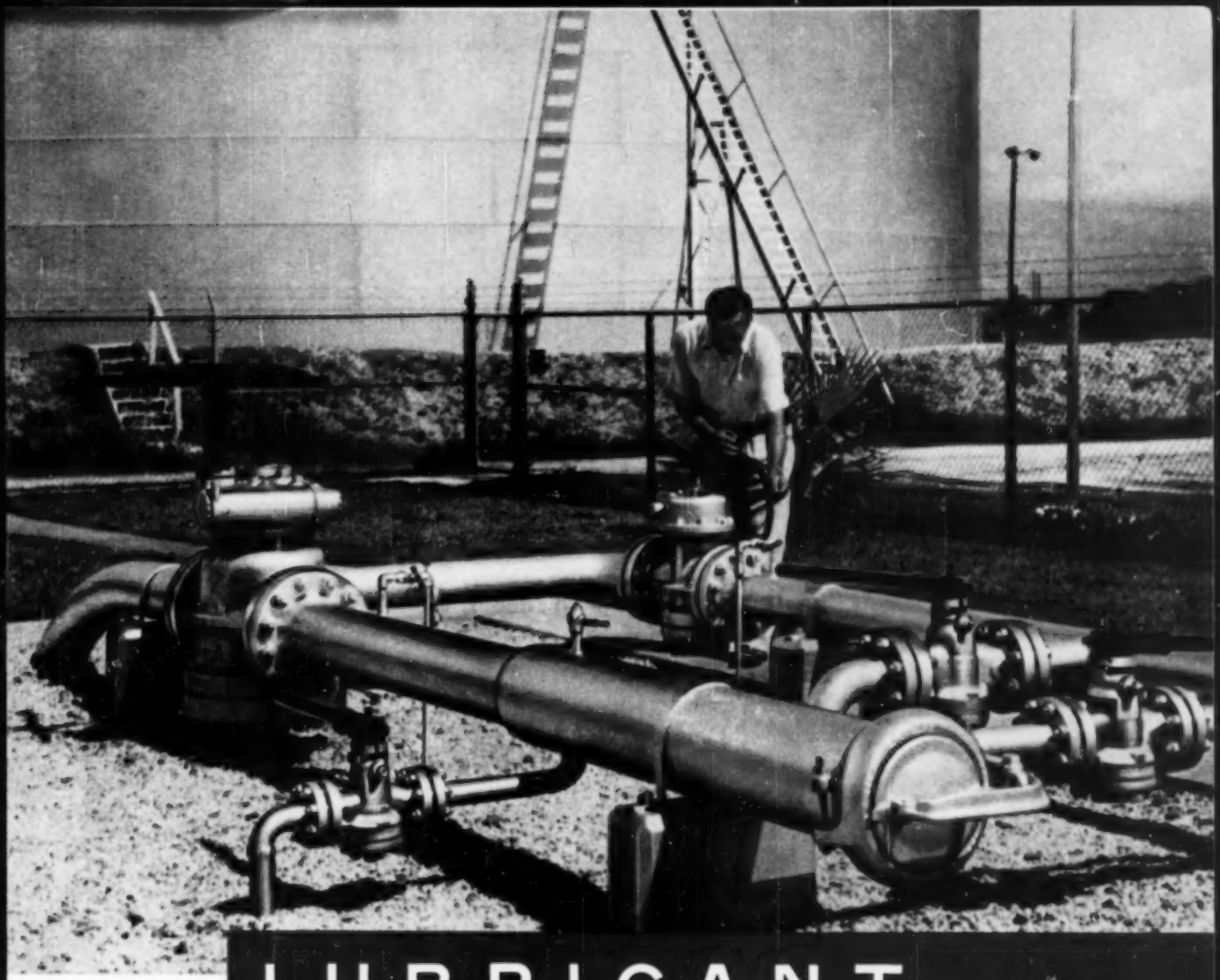
The highest salaries are distributed about equally in small and large companies, as shown below.

	% Above $50,000/Year	
No. Technical Employees	<10	>1000
Years Since B.S.		
11-15	0%	0%
26-30	3%	3%

Effect of Field of Endeavor

In question 26 of the Questionnaire, members were asked to identify their activities according to their main field of endeavor. The fields were classified as follows:

(*Continued on page 30*)



LUBRICANT—
THE NORDSTROM SEAL OF APPROVAL

In any valve, if a small leak starts, high repair and replacement costs are coming up. And, if the valve is in an often-operated manifold, trouble comes to a head sooner.

Unless . . . .
. . . . the valve is a Nordstrom.

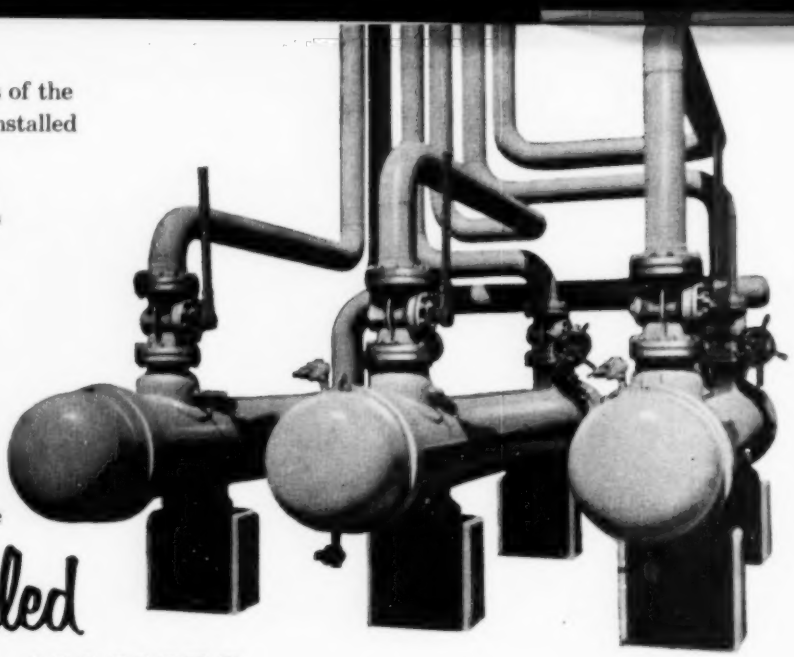
Nordstrom valves have an extra seal against those small leaks. In Nordstrom valves, an even film of plastic lubricant surrounds the valve ports, sealing off the line fluid and at the same time filling any minute point of wear. Further, since there is no seat or disk in the eroding stream of flow, the chances for wear are cut to a minimum.

It's that extra seal of lubricant that has won approval for Nordstrom valves in hundreds of services where other valves aren't quite good enough.
Rockwell Manufacturing Company, Pittsburgh 8, Pa.

ROCKWELL Built Nordstrom Valves
Lubricant-Sealed for Positive Shut-Off
Another Rockwell Product

Regardless of the process, regardless of the piping arrangement, all valves are installed to do the same job:

TO CONTROL FLOW



Some valves do the job better than others. Some valves operate more easily than others in an emergency. Some valves stay tighter longer than others. That's because some (like these) are

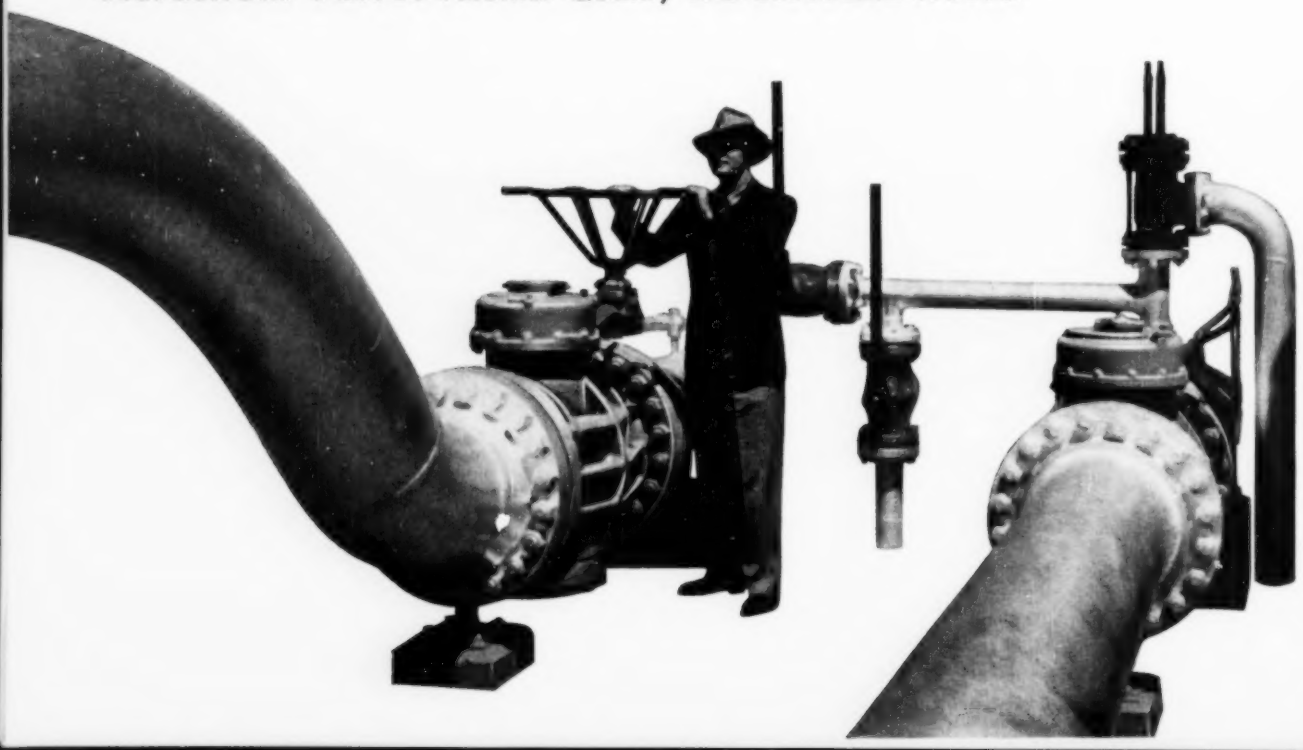
Lubricant-Sealed NORDSTROM VALVES

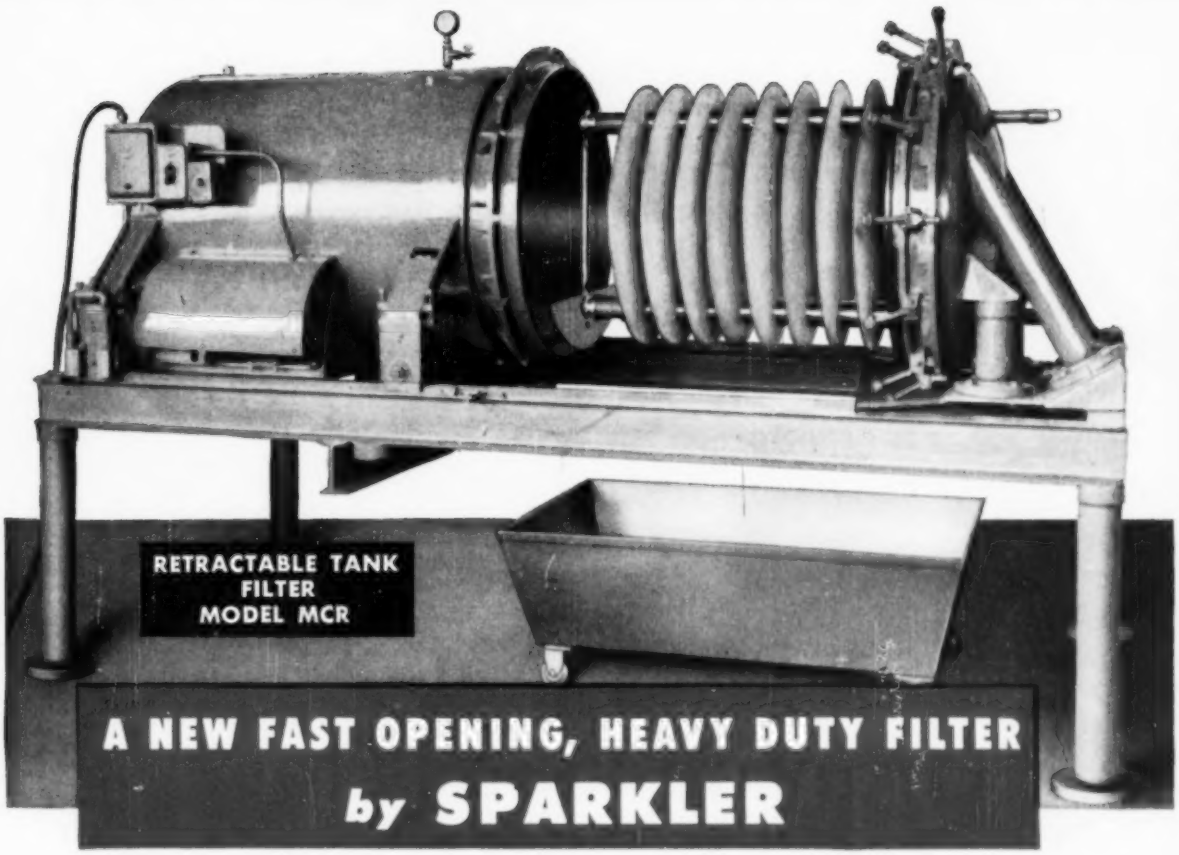
Nordstrom valves have a built-in lubricating system. The lubricant does two important things—it keeps the plug easy to turn so the valve shuts and opens in an instant when it is supposed to; it seals against the small leaks that become big and expensive and perhaps dangerous.
That's why Nordstrom valves

ARE YOUR BEST BUY

Rockwell Manufacturing Company, Pittsburgh 8, Pa.

Nordstrom Valves Another Quality **ROCKWELL** Product





A NEW FAST OPENING, HEAVY DUTY FILTER by SPARKLER

60 Second opening or closing without disconnecting piping. Available in sizes from 100 to 2000 sq. ft. filtering area.

This new retractable tank model MCR filter opens up a new phase in filtering that will lower the cost materially in many industrial fields.

One movement of a handle releases all head bolts simultaneously, a flip of a switch and the retractable tank moves back, stopping automatically, leaving the plates exposed for hand cleaning. All in less than 60 seconds. Pipe connections are all in the stationary filter head so no disconnecting of piping is necessary. This gives you the fastest action, time-saving, labor-saving tank opening ever engineered in a filter.

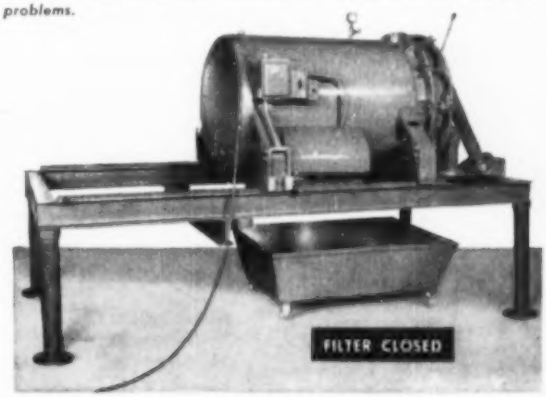
Jet spray tubes can be supplied in this filter with automatic breaking head seal for water supply. With the jet spray the cake can be washed off with pressure spray, backwashed, or a combination of jet spray and backwashing employed for cleaning the plates.

The retractable tank Model MCR Filter fills the need for a large capacity filter that can handle heavy residue fluids and for removal of large percentage solids. The plates can be spaced any distance apart to accommodate a heavy or thin cake depending on requirements.

The circular double surface screen plates are reinforced to withstand extremely high filtering pressure without danger of collapsing.

Filter tanks can be supplied in mild steel, stainless steel, or other metals to meet chemical requirements. Tanks can be rubber lined or plastic lined for corrosion resistance. Each filter including valves and piping is engineered to perform the job required.

Write for specific information about this new filter pertaining to your particular product. Personal attention will be given to your filtering problems.



SPARKLER MANUFACTURING COMPANY • MUNDELEIN, ILLINOIS

Sparkler International Ltd.
Prinsengracht 876, Amsterdam, Holland

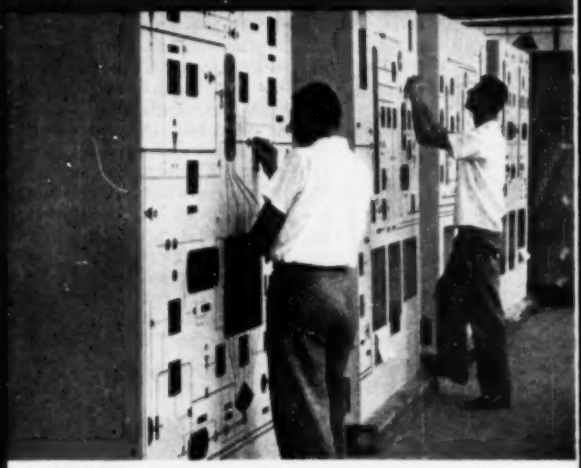
Sparkler Western Hemisphere Corp.
Mundelein, Ill., U.S.A.

OPERATOR'S JOB IS EASIER
when he has this convenient panel at his service. This board is just one section of a large control center, from which an intricate process is regulated.

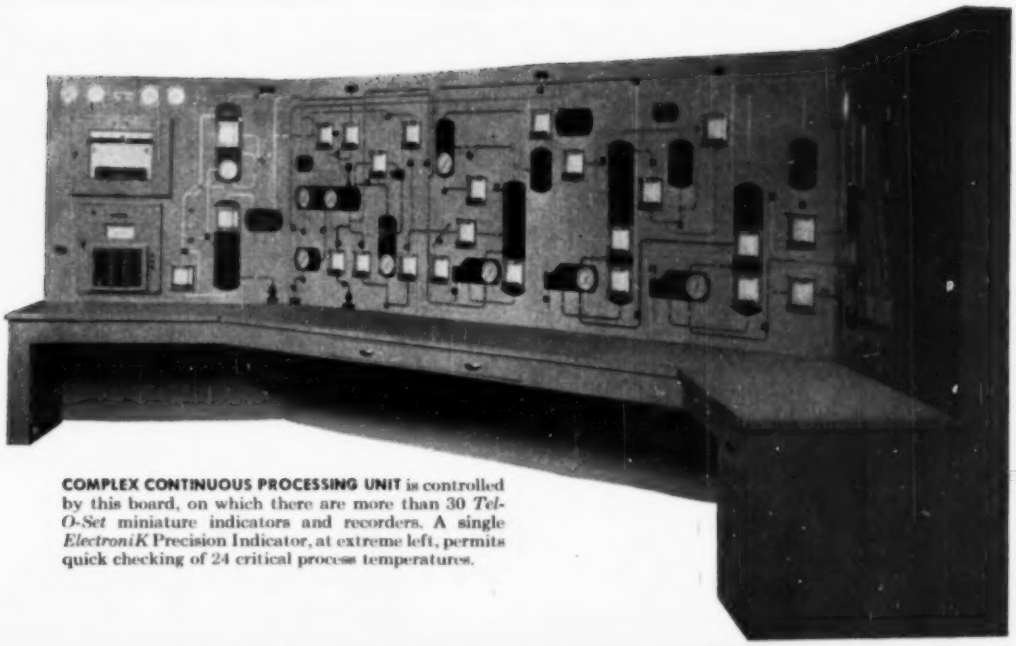
Graphic Panels for modern process control...

These companies . . . and many more
use Honeywell Graphic Panels

Bechtel Corporation
C. F. Braun
Canadian Oil Refineries
Catalytic Construction Co.
Cooperative Refinery Association
Day & Zimmerman Inc.
Derby Oil Co.
Farmers Union Central Exchange Refinery Inc.
The Fluor Corporation Ltd.
Foster Wheeler Corp.
Great Lakes Refinery
Imperial Oil of Canada
Inter-Mountain Chemical
International Refineries, Inc.
Kanotex Refining Co.
The Lummus Co.
Northwestern Refinery
Pan-Am Southern
Phillips Petroleum Co.
The Refinery Engineering Co.
Rohm & Haas Co.
Shell Oil Co.
Sinclair Refining Co.
Socony-Vacuum Oil Co.
Southwestern Engineering Co.
Standard Oil Co. of California
Standard Oil Co. of Indiana
Standard Oil Co. of New Jersey
Sunray Oil Corp.
Sutherland Refiner Corp.
Union Oil Co. of California
Vickers Petroleum



HONEYWELL PANEL DIVISION includes complete panel assembly facilities. All instruments, controllers, accessories, and back-of-panel wiring and piping are carefully assembled—then subjected to rigorous tests which simulate actual process conditions, to assure trouble-free start-up on the job.



COMPLEX CONTINUOUS PROCESSING UNIT is controlled by this board, on which there are more than 30 *Tel-O-Set* miniature indicators and recorders. A single *ElectroniK* Precision Indicator, at extreme left, permits quick checking of 24 critical process temperatures.

a progress report from Honeywell

THROUGH centralized graphic instrumentation by Honeywell, many companies are realizing the dollars-and-cents benefits of greater operating efficiency, simplified supervision, and improved coordination of complex processes. The panels shown on these pages typify the many which Honeywell has supplied for a variety of applications.

Into each panel—large or small—goes a wealth of specialized engineering experience, which translates process requirements into a coordinated design. Attractive appearance is combined with functional arrangement of every part for maximum operating convenience and efficiency.

Superior workmanship is the hallmark of Honeywell panels. Skilled technicians use special techniques to produce completely wired and assembled boards, in a separate manufacturing division devoted exclusively to panel work.

Drawing upon the most complete line of conventional and miniature instruments, Honeywell is prepared to develop the centralized control your process needs . . . whether it be a full graphic, semi-graphic or conventional panel—a control cubicle or a complete control room.

Our local engineering representative will be glad to discuss how *Panels by Honeywell* can help your process. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4427 Wayne Ave., Philadelphia 44, Pa.

● **REFERENCE DATA:** Write for reprint of article "Centralized Graphic Panels—Unlimited," *Instrumentation*, Vol. 6, No. 1

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls

KRYSTAL

Struthers Wells

VACUUM CRYSTALLIZER FOR PRODUCING NON-CAKING, UNIFORM CRYSTALS

Crystalline materials such as potassium chloride produced in the Krystal equipment illustrated are uniform in size, non-caking, dust free, and easily separated from mother liquor in filter or centrifuge.

Krystal crystallizers can be operated for long periods without shutdown time for cleaning. Thus, Krystal produces crystalline materials of highest quality with greatest economy.

Our crystallization engineers are available for consultation on your crystallization problems.

Write for Bulletin 50-A which describes the principles and applications of Krystal crystallizer equipment.

KRYSTAL

stands for quality throughout the world

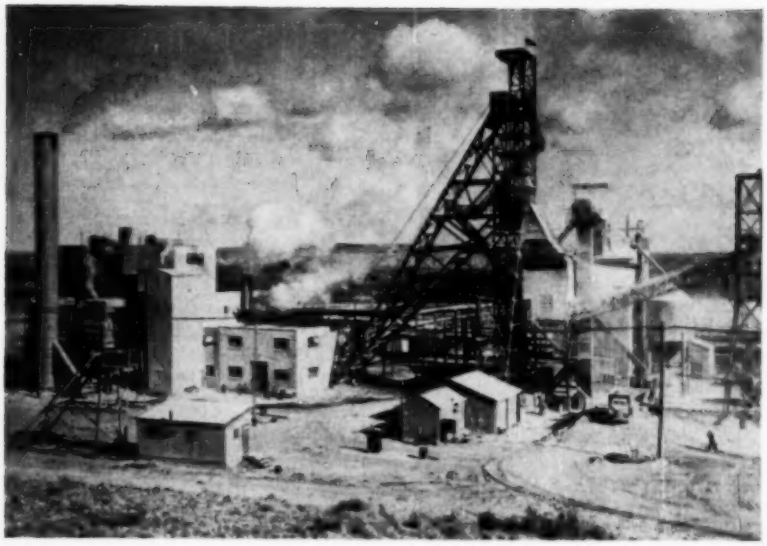
Struthers Wells

STRUTHERS WELLS CORPORATION

WARREN, PA.

Plants at Warren, Pa. and Titusville, Pa.

Offices in Principal Cities



Left, Soda ash plant, showing power house on left; mine-shaft-head frame and ore-storage stocking-out conveyers and support frame at extreme right; crusher building at rear right of mine-shaft-head frame.

Below, Mine shuttle car discharging onto belt conveyer.

Soda Ash Plant at Westvaco, Wyo.

The new $20,000,000 soda ash plant at Wesvaco, Wyo., which taps an underground supply of almost pure trona, is on stream. Though owned by Intermountain Chemical Co., a subsidiary of Food Machinery and Chemical Corp. and National Distillers Products Corp., the plant is being operated by F.M.C.'s Westvaco Chemical Division. The trona mine and plant, which are located about 20 miles west of Green River, Wyo., have an annual capacity of 300,000 tons, according to C. A. Romano, resident manager.

The seam of trona, which lies roughly horizontal, consists of a layer of crystals varying in color from light tan through rose to green and gray and is 5 to 11 ft. thick. Its principal impurity is about 5% by weight of shale.

Because the shale is insoluble in water, Wyoming trona is easily purified. Crude trona is mined, crushed to −20 mesh, and dissolved in water, and the insoluble shale is filtered out. The solution is decolorized by contacting with activated carbon; sesquicarbonate is crystallized out in triple-stage Krystal vacuum crystallizers and converted to refined soda ash in rotary calciners.

The trona deposits in Sweetwater County, Wyo., were discovered in 1938 when the Mountain Fuel Supply Co., while drilling for oil and gas, put down a prospect hole, the core of which was found to contain relatively pure trona at a depth of about 1,500 ft. From this first core, the deposit appeared to be 10 to 20 ft. in thickness. This discovery was confirmed in 1940 by the Union Pacific Railroad, and subsequent borings proved the huge size of the deposit.

In 1944 Westvaco began a program of diamond drilling on the site. The first working shaft, 12 ft. in diameter and concrete lined, was sunk to the depth of the bed in 1947. Conventional mining techniques were used. Soon after, a surface pilot plant was put on stream. Over $2,000,000 was invested in the initial mine development and the pilot plant before present soda ash production facilities were initiated. A second mine shaft, 14 ft. in diameter and concrete lined, has been sunk. The present plant was constructed by Bechtel Corp. Underground over 7 miles of mine tunnels have been drilled. The main haulage, 3,000 ft. long, consists of six parallel tunnels, each 12 ft. wide and 7 ft. high, from which tunnels angle off into the ore body. The ore is drilled and blasted, loaded onto shuttles, and dumped onto conveyers. After being crushed, it is dropped onto a storage hopper which feeds automatically into skip hoists. Two skip hoists move up and down alternately, each skip bringing about 7 tons of crushed ore to the surface every 2 min.

Above ground the crushed ore is moved to the purification plant. Processing operations require 600,000 gal. of water daily, pumped through a 10-mile pipe line from the Green River into a million-gallon reservoir on the property. A 20-mile pipe line delivers natural gas.

Soda ash, America's third largest chemical, is consumed at about 5 million tons a year, and the rate is increasing by 170,000 tons annually. The Wyoming trona bed has been estimated to contain 250 million tons, from which 170 million tons of pure soda ash can be produced, enough to supply the entire needs of U. S. industry for the next 34 years. Geologists believe that unproved reserves may very well be in excess of this amount.

Completion of the soda ash plant marks the largest single industrial development in the state of Wyoming in recent years. It is visualized by Westvaco officials as the forerunner of a great chemical industry in the intermountain West.

(*More News on page 31*)

A.I.Ch.E. SURVEY

(*Continued from page 22*)

1. Research and development
2. Design (process, plant, mech. eng., drafting, etc.)
3. Plant operation
4. Teaching, education
5. Consulting
6. Economics, market analysis, purchasing, financial, etc.
7. Sales (development, technical, advertising, etc.)
8. Placement, training or employee, labor, or public relations
9. Management
10. Special services, such as patents, library, literature research, safety, etc.
11. Other unlisted fields

These eleven groups were studied to establish differences, if any, in their incomes. Groups 6, 8, 10, and 11 contained too few individuals to permit reliable estimates of income trends. Results for the other seven groups are shown in summarized form in Table 3. It is interesting that the largest number of members, one third of those replying, were in the Research and Development field.† The median incomes for this group are accordingly close to the over-all median (as indicated by the data of Table 2 for the larger companies). The same comment applies to the 25th percentile. The next largest groups are in Design and Operation, which have similar income patterns. Operating engineers appear to enjoy a salary advantage in early years over their Research and Design contemporaries; but in later years the Research and Development group seems to take a definite lead. All these groups are supposedly non-Management, since Management is a separate category. On the other hand, only one answer was permissible, and it is possible that Management *level* people might have checked Research and Development as their major field of endeavor.

Income of members in Sales and allied services about parallels that of Research members, which may well be contrary to popular opinion.

Relatively few Consultants replied to the questionnaire, and these seem to be above average in earning power.

The main differences occur in the Teaching and Management groups, which is of course not surprising. The Management group is clearly high; and it undoubtedly helps to raise the levels of income reported in Tables 1 and 2 and in the figures. The Teachers, following tradition, are low, but are nevertheless surprisingly close to their industrial brethren of non-Management groups. This result suggests that the professors, especially those in the upper percentiles, have found ways to supplement their academic salaries.

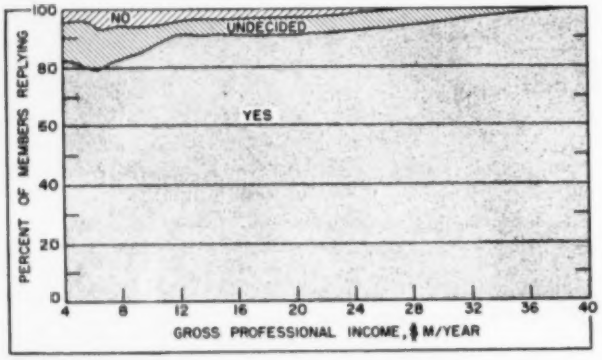


Fig. 4. Career satisfaction correlated with salary.

Career Satisfaction

Question 15 asked if members felt they had made the correct choice of career in becoming chemical engineers. A definitely affirmative response was received, as shown in the earlier article (*2*) and again below:

	Total Members
Yes	6,519
No	422
Undecided	808

These replies have been further analyzed by correlation with answers to Questions 20 (salary) and 16 (professional recognition by employers). Results of the salary correlation are given in Figure 4. The size of the undecided group is markedly reduced as annual incomes grow from $8,000 to $14,000. Little other change in the distribution of replies occurs up to a salary level of $25,000, beyond which there is apparently no dissatisfaction. Some uncertainty regarding correctness of choice persists among a few—even at an income of almost $40,000/year! One might conclude that factors other than dollars are significant in a man's degree of career satisfaction.

Question 16 asked "Does your employer recognize you as a professional man?" Total replies were again affirmative as follows:

Yes	6,484
No	482
Undecided	513
Not an Employee	231

Correlation of these replies with those to the question on correctness of career choice is presented in Table 4.‡ Both the number of individuals and the per cent of the total respondents they represent are given for each group. The percentages are additive both vertically and horizontally. Thus, 5,566 out of 7,439 employee members, or 75%, are recognized as professionals and feel they chose correctly, while, for some reason other than lack of professional recognition, 3.9% feel that they made the wrong choice. A total of 6.4% say that their employers do not treat them as professional men, yet two thirds of these (4.2%) are satisfied with their choice of career. Only 1%, or 73 members, are both unrecognized and dissatisfied. Although the fraction dissatisfied is higher in the unrecognized group (1 : 4.2 vs. 3.9 : 75), failure to receive professional recognition does not seem to be a problem of serious proportion among A.I.Ch.E. members.

Conclusion

On the whole, the results of this survey indicate that A.I.Ch.E. members are well satisfied with their choice of career and have achieved professional recognition from their employers. The professional earnings of the group increase steadily through the years. Although there are wide individual variations in income, these variations depend little upon college degree, size of company, or even field of endeavor, and are presumed, therefore, to be largely a matter of individual performance. Incomes in teaching are somewhat lower than those in industry, and the highest incomes are found in the Management group.

Literature Cited

1. Isbin, H. S., *Chem. Eng. Progress*, **48**, 237 (1952).
2. Smith, L. B., *Chem. Eng. Progress*, **49**, 17 (1953).
3. Van Antwerpen, F. J., et al., *Chem. Eng. Progress*, **48**, 419 (1952).

† This could mean that research and development people are the largest group in the A.I.Ch.E., or, it could mean that research and development members were the most interested in responding to the questionnaire.

‡ Totals in Table 4 will be slightly less than totals for the individual questions, because of the rejection of improperly checked replies.

CANADIANS TRY FLOTATION ON URANIUM ORE

A process for concentrating the large low-grade uranium-ore deposits of Canada is being sought by five members of the University of Saskatchewan, who presented their findings to the Chemical Institute of Canada.

I. J. O. Korchinski, G. A. Craig, E. B. Tinker, S. D. Cavers, and A. B. Van Cleave have tackled the problem by using flotation methods. "Although Canadian uranium ores have not so far responded well to preconcentration by flotation," the authors state, "if leaching were to be used as a step in the recovery process even a twofold concentration of the ore would result in worth-while savings in handling costs." In the flotation operation, particles of one mineral are floated by means of air bubbles from a suspension of particles of two or more minerals in water. The surface of the mineral to be floated is coated with a collector. In their work so far, the authors have not found a satisfactory collector.

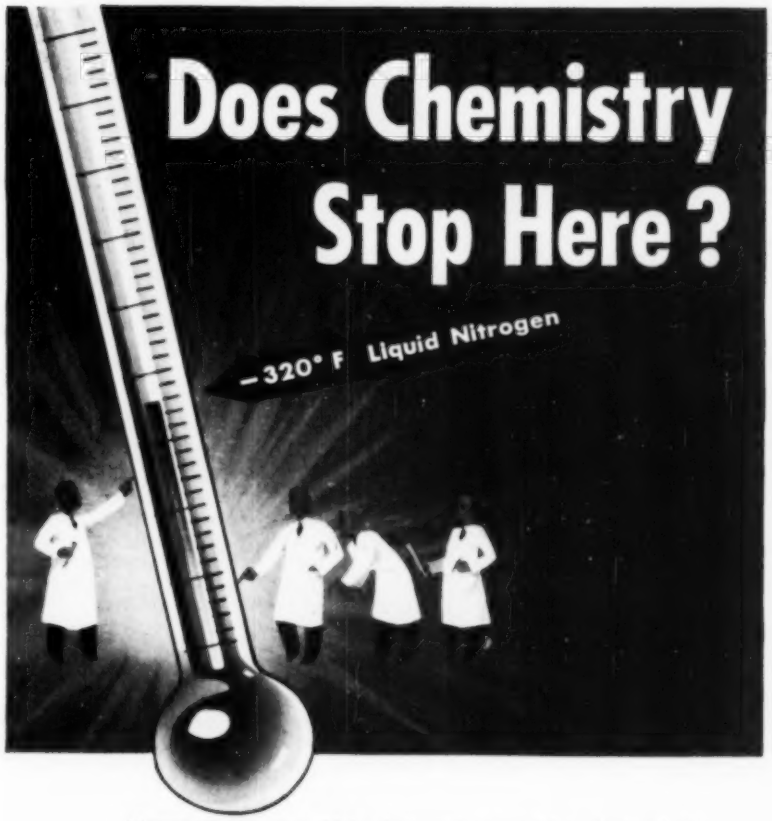
NEW ELECTRONIC PARTICLE-SIZE ANALYZER

An instrument for determining the particle-size distribution of powdered materials has recently been placed in production by the Sharples Corporation Research Laboratories, Bridgeport, Pa. Known as the Sharples Micromerograph, the instrument allows powder particles which are dispersed in air through a tube to settle under the action of gravity onto a servoelectric balance. The balance yields a continuous record of the weight of powder settled, plotted against time. Through the application of Stokes's law, a particle-size distribution curve is obtained.

The Micromerograph, according to its designer, reduces the time required for a test run to as little as 15 min., and by utilizing a relatively large sample (about 0.1 g.), containing billions of discrete particles, eliminates large statistical errors. Compressed gas is used to inject the powder sample into the sedimentation tube through a deagglomerator.

JOINT MEETING OF A.S.E.E. AND E.C.P.D. IN FALL

A joint meeting of the American Society of Engineering Education and the Engineers' Council for Professional Development will be held in New York on October 14 to 17. Principal topics for open discussion will be accrediting and the current supply of and demand for engineers. Gen. A. G. L. McNaughton of Canada and Horace Liversidge are expected to be the luncheon and dinner speakers on Friday, Oct. 16.

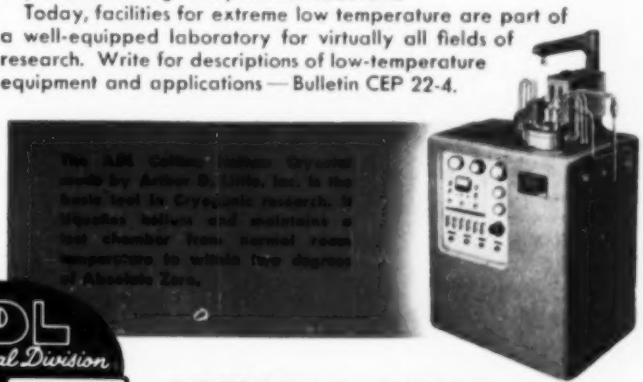


Normally when we think of chemistry, we think of chemical activity at room temperature and above. Yet it is possible that important anomalous behavior will appear in a very small temperature interval . . . perhaps near Absolute Zero.

Although research near absolute zero (−460° F) is relatively new, it is contributing daily to the metallurgists' understanding of the properties of metals . . . And physicists have already discovered promising low-temperature phenomena, such as superconductivity, and are now looking toward their practical application.

At present, low-temperature chemistry is mostly an interesting combination of words. But this is changing. Chemicals which are extremely reactive at ambient temperature may conceivably be stabilized at low temperature. Knowledge of what happens at extreme low temperature can be of particular value to chemists as a key to the explanation of high-temperature reactions.

Today, facilities for extreme low temperature are part of a well-equipped laboratory for virtually all fields of research. Write for descriptions of low-temperature equipment and applications — Bulletin CEP 22-4.



ADL Mechanical Division

ARTHUR D. LITTLE, Inc.
MECHANICAL DIVISION
30 MEMORIAL DRIVE, CAMBRIDGE 42, MASS.

for valving corrosive and "hard-to-handle" fluids . . .

HILLS-McCANNA

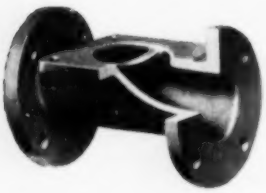
offers over 20,000 different "custom-made" assemblies on a standardized basis

32 standard operators

Methods of operation for Hills-McCanna Valves include handwheel and lever operators, sliding stem, air and hydraulic cylinders, diaphragm motors and electric motors in a variety of types.

14 standard diaphragms

Diaphragms, the heart of Hills-McCanna Valves, are offered in the widest choice to best suit your individual needs; 5 types of rubber, 3 of Neoprene plus Hycar, butyl, Tygon, Compar, special polyethylene and Kel-F.



48 standard body materials

Bodies for Hills-McCanna valves are furnished in cast iron, with or without such linings as rubber, glass, lead, etc.; in any machinable alloy or in such materials as Karbate, stoneware, porcelain, etc.

By offering such a broad selection of operators, diaphragms and bodies, Hills-McCanna is able to furnish so many standard combinations that the user is in the position of being able, in most cases, to find the exact valve that best fits his individual requirements. There is virtually never any need to adapt to your service a valve developed for someone else's needs.

The 36 page catalog No. V-52 gives full details on all Hills-McCanna Valves. Write for your copy. HILLS-McCANNA CO., 2438 W. Nelson St., Chicago 18, Illinois.

HILLS-McCANNA

saunders patent diaphragm valves

Also Manufacturers of Proportioning Pumps Force Feed Lubricators • Magnesium Alloy Castings

BOARD IS PRODUCED FROM WOOD WASTES

Production of an all-wood panel from wood wastes by a continuous process has been announced by Bartrev, Ltd., a British firm. The Bartrev press, according to its developers, resembles a modern paper-making machine in that resin-treated wood particles are fed in a continuous carpet onto an endless stainless-steel belt where they are bonded by heat and pressure and emitted as a continuous length of board. The finished product is 48 in. wide, of a controlled thickness of 3/16 to 3/4 in. and density of 0.5 to 0.8 or higher, and can be worked with hand or power tools.

Wood chips move along conveyor to Bartrev press, which converts them into continuous board.

The raw materials consist of wood particles of varying moisture content, density, size, shape, etc., derived from lumber-mill waste, which are ground and blended with quick-setting resins and polymerized. The press consumes up to 3 tons of raw material per hour and can produce 120 sq.ft. of board per minute.

The press is sold in the United States through Aries Fiberboard Corp., New York.

GOODRICH BUILDS CHEMICAL PLANT

Plans to build a plant to manufacture acrylonitrile at Calvert City, Ky., have been announced by B. F. Goodrich Chemical Co. The plant will have an annual capacity of 24,000,000 lb., will cost $8,500,000, and is scheduled to begin operation in the fall of 1954 on a site adjacent to Goodrich's vinyl chloride monomer plant.

U. S. CORROSION CONTROL STUDIED BY EUROPEANS

A group of chemical engineers and management executives representing the chemical industries of eleven Western European countries spent the past month examining American preventive maintenance techniques. The twenty-seven men in the group came from Austria, Belgium, Denmark, France, Italy, The Netherlands, Norway, Sweden, Turkey, the United Kingdom, and Western Germany and were sponsored jointly by the Mutual Security Agency and the Organization for European Economic Cooperation.

After preliminary conferences with corrosion engineering experts, the group divided into three, to undertake detailed studies of heavy chemicals, light chemicals, and petrochemicals through visits to leading chemical firms and research laboratories throughout the country.

INDUSTRIAL HYDRAULICS MEETING FOR FALL

The National Conference on Industrial Hydraulics held annually at the Illinois Institute of Technology will convene on Oct. 8 and 9. R. E. Peck, professor chemical engineering at the Institute, is among the members of the committee. The conference director will be O. E. Teichmann of the Armour Research Foundation, and Carl E. Schmitz, vice-president of the Crane Packing Co., will be associate director.

Societies working on the conference are the A.I.Ch.E., A.S.C.E., A.S.M.E., S.A.E., A.S.T.E., Western Society of Engineers, American Society of Lubrication Engineers, Institute of Aeronautical Science, American Society of Agricultural Engineers, and Illinois Society of Professional Engineers.

SPENCER CHEMICAL IN POLYETHYLENE FIELD

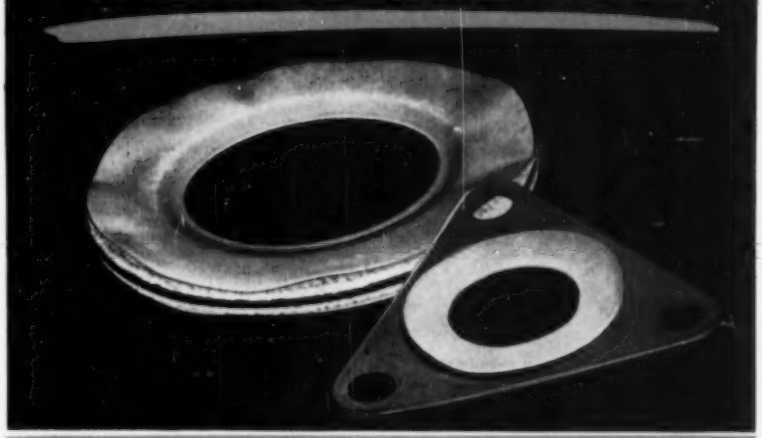
Spencer Chemical Co. recently announced plans for construction of a plant to produce approximately 45,000,000 lb./year of polyethylene. The new plant will be located near Orange, Texas, and is expected to be in operation by the spring of 1955.

Production will be carried on under the basic patents of Imperial Chemical Industries, Ltd., of London.

National production of polyethylene, according to Spencer officials, is about fifty times what it was in 1944, and by 1955, it is estimated by the National Production Authority, it will exceed 350,000,000 lb. annually.

(More News on page 52)

GASKETS with GUTS



Chemiseal MADE OF TEFLON Gaskets

Laugh at Acids, Caustics, Solvents

Chemiseal Gaskets have become standard for corrosion and contamination problems because—made of TEFLON—they are inert to all chemicals excepting molten sodium and fluorine.

Chemiseal Teflon-Jacketed Gaskets are available in any size, with a variety of filler materials suitable for glass, glass-lined, porcelain, Karbate, Haveg, stainless or other metal piping and equipment.

These fillers are protected on both faces and the inside diameter by the chemical resistant Teflon Jacket.

Ask for Catalog No. 1-339 WA.

Chemiseal Snap-On Gaskets, molded from Solid Teflon are available with projections matching grooves in pipe ends of all conical-end glass pipe joints. Ask for Catalog No. 820.

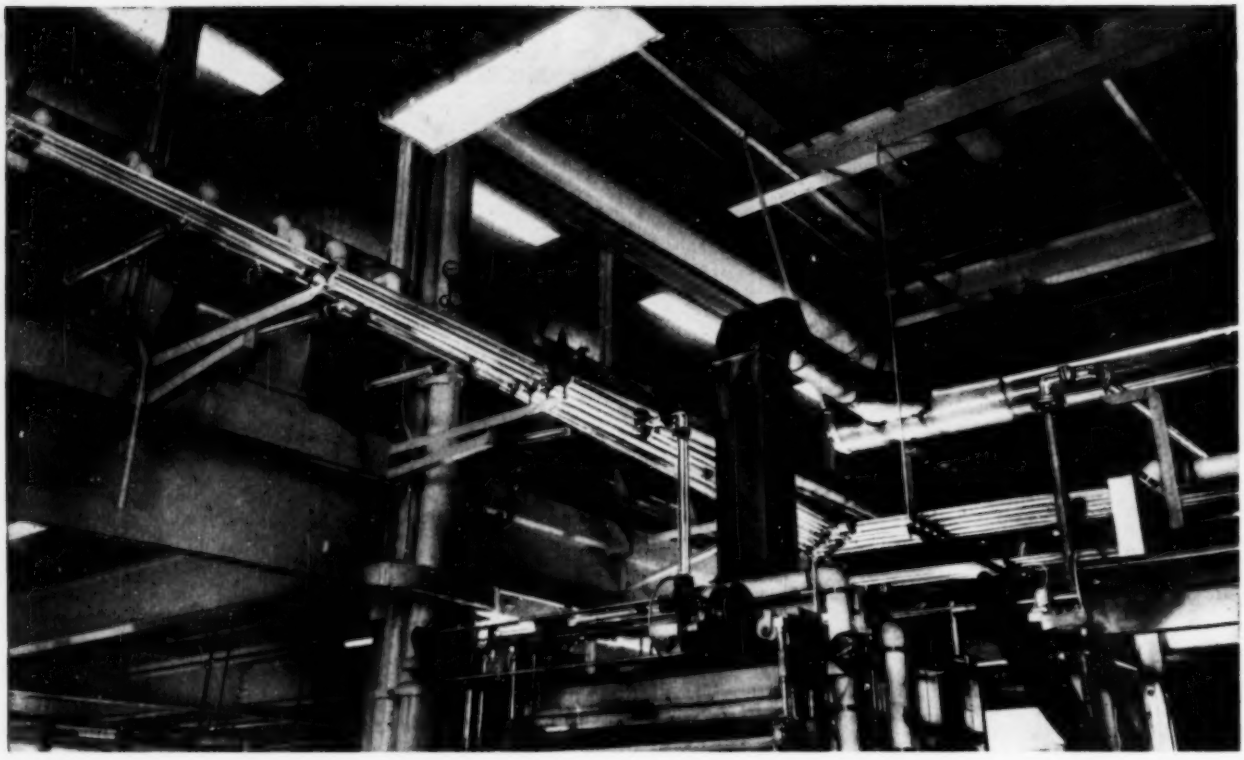
Cut Teflon Gaskets are also available, either as ring or full face gaskets for all standard pipe sizes or for irregular shaped openings. Ask for Catalog No. 310.

UNITED STATES GASKET COMPANY

FLUOROCARBON PRODUCTS DIVISION

CAMDEN 1, NEW JERSEY

Representatives in Principal Cities Throughout the World



How this chemical dye user

protects sensitive products in process

...and gets 2 other advantages with Pyrex® brand Glass Pipe

When Bachman Uxbridge Worsted Mills prepared to select a piping material, they set up three requirements:

1. It must be noncontaminating in transferring highly sensitive dyes from a central mixing station to dye kettles. Dye shadings are extremely sensitive to metallic contamination.
2. It must be easy to clean. And the cleaning had to be positive and provable so that colors could be switched rapidly.
3. It must assure real economy in cost of installation, maintenance and service life.

PYREX brand "Double-Tough" glass pipe met these requirements so well that this Uxbridge, Mass. textile mill has 25 lines in various lengths from 25 to 100 feet.

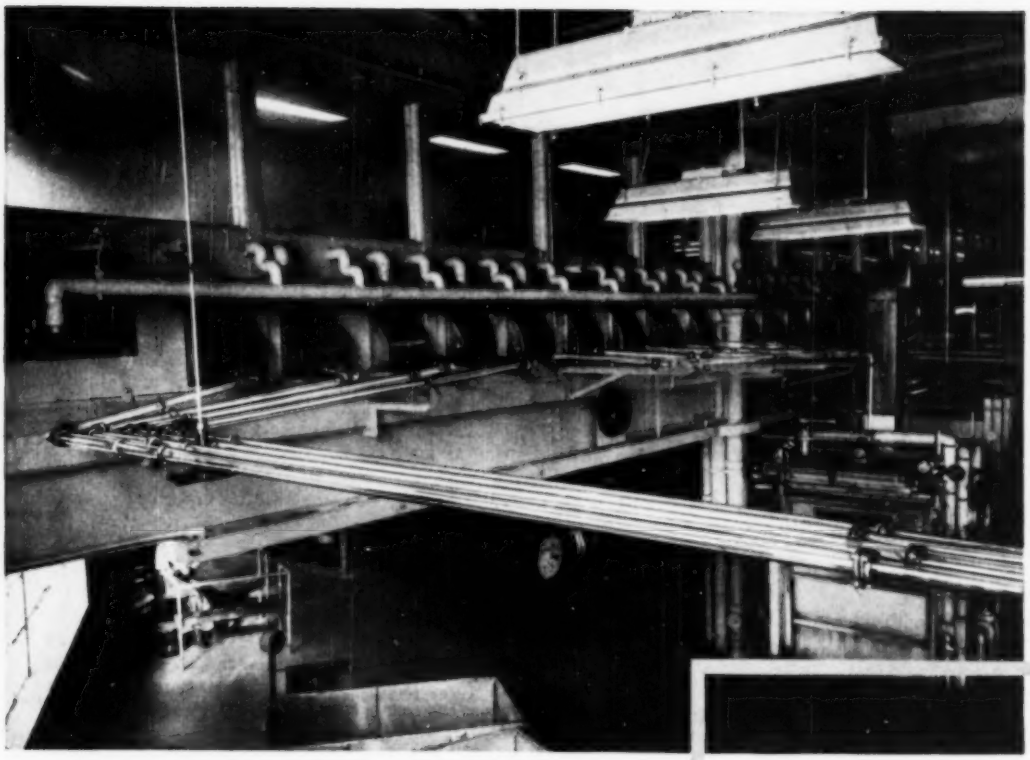
The exceptional chemical stability and corrosion resistance of PYREX pipe makes it ideal for the most sensitive dyes and pharmaceuticals as well as hot, concentrated acids (except hydrofluoric) and mild caustics.

Easy cleaning is assured by its hard, smooth surface, free of pits and truncations. When it is clean, the transparency of glass lets you see that it is clean . . . also enables you to detect air locks and impediments in the lines.

PYREX brand glass pipe is actually the most economical corrosion-resistant piping material on the market today. First cost is reasonable. Your own men can install it. And it is sure to provide long, troublefree service . . . not only because it cannot be eaten away by acids, but because it has a high degree of physical and thermal strength.

The name of your conveniently located, qualified PYREX pipe distributor is listed at right. Contact him today for the facts on this efficient, money-saving material . . . or mail the coupon.

CORNING GLASS WORKS



High chemical stability and easy cleaning are two of the big reasons why 25 lines of PYREX pipe, 25 to 100 ft. in length, are transferring sensitive dyes from central mixing station to dye kettles at Bachman Uxbridge Worsted Mills, Uxbridge, Mass.

Transparency permits observation of flow in lines. Low first cost, easy installation and long service life assure real economy.

The installation described here is typical of hundreds in many different industries. For ideas on how PYREX pipe is serving these industries, send for "PYREX brand Glass Pipe in the Process Industries."

These PYREX brand glass pipe distributors stock the complete line:

BELMONT, CALIFORNIA
Glass Engineering Laboratories

FRESNO 17, CALIFORNIA
Valley Fdy. & Mach. Works

NEW HAVEN, CONNECTICUT
Macalaster Bicknell Company

ATLANTA, GEORGIA
Southern Scientific Company

CHICAGO 44, ILLINOIS
Fred S. Hickey, Inc.

NEW ORLEANS, LOUISIANA
W. H. Curtin & Company

CAMBRIDGE 39, MASS.
Macalaster Bicknell Company

ST. LOUIS 2, MISSOURI
Stemmerich Supply Inc.

LODI, NEW JERSEY
Mooney Brothers Corporation

ALBANY 5, NEW YORK
A. J. Eckert Industrial Sales Corporation

BUFFALO 13, NEW YORK
Buffalo Apparatus Corp.

ROCHESTER 3, NEW YORK
Will Corporation

HATBORO, PA.
Sentinel Glass Company

PITTSBURGH 19, PA.
Fisher Scientific Company

HOUSTON 7, TEXAS
W. H. Curtin & Company

SEATTLE 4, WASHINGTON
Scientific Supplies

TORONTO, ONTARIO, CAN.
Fisher Scientific Company, Ltd.

MONTREAL 3, QUEBEC, CAN.
Fisher Scientific Company, Ltd.

VANCOUVER, B. C., CAN.
Scientific Supplies, Ltd.

CORNING, N. Y. *Corning means research in Glass*

CORNING GLASS WORKS
Dept. CP-7, Corning, N. Y.

Please send me the printed information checked below:

- ☐ "PYREX brand Glass Pipe in the Process Industries" (EA-1)
- ☐ "PYREX brand 'Double-Tough' Glass Pipe and Fittings" (EA-3)
- ☐ "Plant Equipment Glassware for Process Industries" (EB-1)
- ☐ "Installation Manual" for PYREX brand 'Double-Tough' Glass Pipe (PE-3)
- ☐ "PYREX Cascade Coolers" (PE-8)

Name .....

Title .....

Company .....

Street .....

City .....

Zone ..... State .....

MARGINAL NOTES

News of Books of Interest to Chemical Engineers

The "How" of Statistics Made Easy

Statistical Methods for Chemical Experimentation, W. L. Gore, Interscience Publishers, Inc., New York (1952), xi + 210 pp., $3.50.

Reviewed by Elmer P. Foster, E. I. du Pont de Nemours & Co., Augusta, Ga.

This book can be a helpful introduction to the experimenter in chemical engineering. It can be easily read and understood by one not familiar with the field.

This is the first of a series of manuals which the publisher states "will provide a straightforward description of laboratory procedures and methods for the evaluation and recording of experimental results." The author says this monograph was prepared because "none of the current books on statistical methods . . . give an adequate description of how the present knowledge on design of experiments can be applied in chemical investigations."

The book was written for the engineer or chemist to use as an introduction in applying statistical methods in designing experiments. The experimenter who has wanted to use statistics and has had difficulty in finding the correct trail through the forest of publications, without a consultant's aid, will welcome it.

The first four chapters are devoted to an introduction to statistical concepts, reliability of estimates and analysis of variance. The treatment is incomplete, but it serves the announced purpose of introducing the experimenter to these subjects. These chapters fail to state basic assumptions and limitations or to discuss the power of these tests.

The fifth chapter is devoted to designing experiments. Starting with a simple experiment, the author illustrates the failure of the classical experimental method to cope with interactions. He then illustrates increasingly complex techniques for handling more complex problems. This chapter is the "meat" of the book. Here is shown how different designs can be used in solving experimental problems.

Chapter VI is devoted to fitting a regression line to the data after these have been collected and analyzed to determine if variations are significant. The author emphasizes the use of least square calculations to fit any type of curve to the data.

Chapter VII, the last chapter, treats chi-square tests and binomial probability. This chapter may have been added as an afterthought, for, in our opinion, these subjects belong with the earlier chapters on basic statistical concepts. We recommend that this chapter be read after Chapter III.

The appendices include tables of the normal curve, the Student t distribution, chi-square distribution and the F distribution. An index of formulas serves as an aid which can be useful for the neophyte.

The major shortcoming is a small page size which necessitates carrying an involved problem over several pages. Another defect likely to cause confusion is the use of symbols which do not conform to historical use by statisticians.

In an abbreviated bibliography the author has listed books on statistical methods and he has included a short statement giving his opinion of each book.

This reviewer believes that this monograph will interest the experimenter in statistical procedures enough so that he will go on to more complicated texts on the subject.

Food for More Thought

Elements of Food Engineering, Vol. I. Milton E. Parker, E. S. Harvey, and E. S. Stateler. Reinhold Publishing Co., New York (1952), 386 pp., $8.75.

Reviewed by W. L. Faith, Corn Products Refining Co., Argo, Ill.

This book, the first of three proposed volumes, has emblazoned on its jacket, "The first book in a new and beckoning field . . . introducing the student and general reader to the new profession of food engineering from a unit operation and unit process viewpoint."

The authors define food engineering by saying that it "is concerned with the design, construction, and operation of industrial processes or plants in which controlled physical, chemical and biological changes in food may occur, wherein the analysis and prediction of their costs under specified working conditions are provided." A list of fourteen basic unit operations is given, some of which will appear strange and farfetched to the chemical engineer. There is mention of the unit operation, "instrumentation"! However, aside from frequent allusions to the versatility and ability of the food engineer, and the promise that Volume II "will be concerned with . . . the fundamentals of design, construction, and operation of methods and equipment . . . ," there isn't, in this reviewer's opinion, any engineering in the book.

Actually Volume I is a textbook of elementary food technology. The first hundred pages (four chapters) contain a general discussion of world food problems and the scope of the food industry. Seemingly out of place are seven pages on "Food Processing in Illinois." The final nine chapters have a single general title "Refined Foods Processing."

Each chapter usually includes a discussion of the composition of raw materials and products, and the uses of the product, general process descriptions, some of the history of the particular food, a discussion of storage problems and trade terms, and a statement of government and trade specifications.

It is doubtful if chemical engineers will be interested in this work. On the other hand, many will await publication of Volume II.

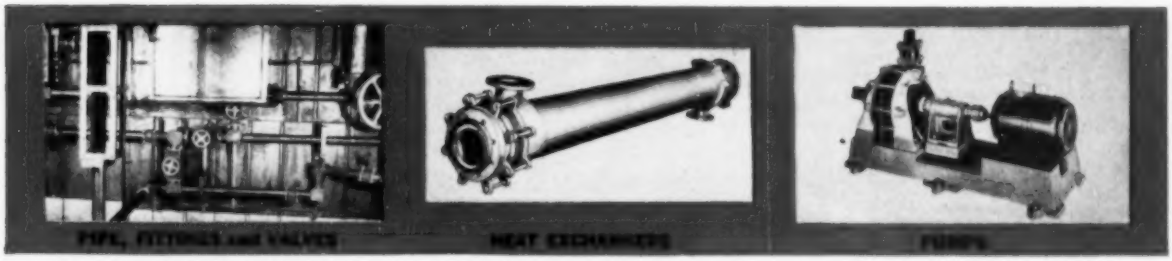
Tool Engineers' Data Book. G. J. Gruen. Reinhold Publishing Corp., New York (1953), 219 pp. $5.50.

The practicing tool engineer and designer will find in this little book the tables, formulas, constants and specifications he needs. It has readily available information on standard specifications, physical properties, spot identication methods, tables and formulas, and definitions of terms. The book contains a minimum amount of explanations and footnotes. Students, too, will find the material logically arranged, suitable as a reference for courses in machine and tool design, mechanical engineering and metallurgy. The aim throughout has been to enable the practicing engineer to obtain results quickly and accurately.

(*More Marginal Notes on page* 38)

THE NATIONAL CARBON *LINE*

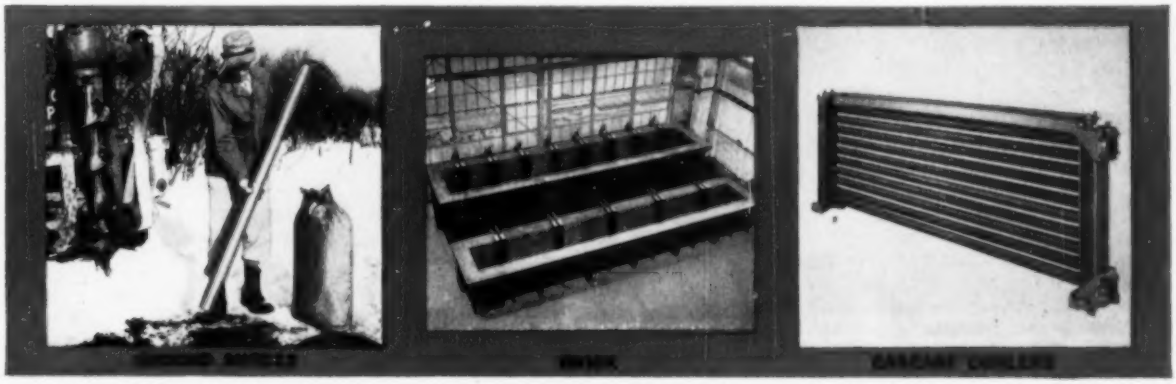
Specify "National" Carbon and Graphite and "Karbate" Impervious Graphite Equipment for Processing and Conveying Corrosive Fluids.



For industry's toughest fluid-conveying requirements. Easy to install and maintain with simple hand tools. Catalog Section S-7000.

Standard or custom-built; shell and tube, concentric and immersion types in stock sizes. Catalog Sections S-6620 S-6670, S-6740, S-6750.

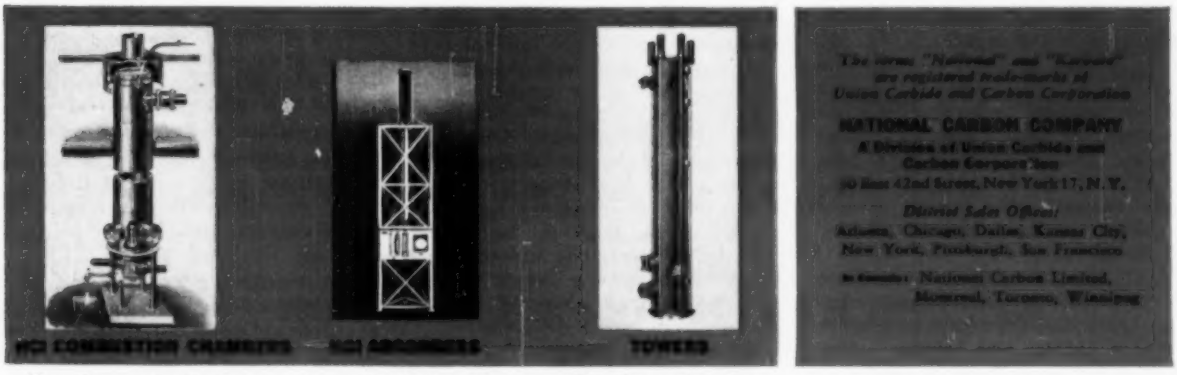
The centrifugal pump for handling corrosive fluids. Rugged, trouble-free design. Handling capacities to 800 G.P.M. Catalog Section S-7200.



"National" Graphite Ground Anodes for cathodic protection of buried or submerged metal structures. Catalog Section S-6510.

Accepted material for lining tanks, towers, digesters and other vessels containing corrosive chemicals. Catalog Section S-6210.

New "Karbate" coolers feature standardized, sectional construction...high heat-transfer rate ... low initial cost Catalog Section S-6820.



Versatile, standard equipment for hydrogen chloride synthesis. Burns moist gases. Simple in operation. Catalog Section S-7530.

Compact, light-weight unit produces up to 20 tons per day of 22° Baumé acid. Minimum installed cost. Catalog Section S-7460.

For absorption, fractionation, scrubbing. Easily erected from standard sections and components. Catalog Section S-7350.

The terms "National" and "Karbate" are registered trade-marks of Union Carbide and Carbon Corporation

NATIONAL CARBON COMPANY

A Division of Union Carbide and Carbon Corporation

30 East 42nd Street, New York 17, N. Y.

District Sales Offices

Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

In Canada: National Carbon Limited, Montreal, Toronto, Winnipeg

For further information write to National Carbon Company

MARGINAL NOTES

(*Continued from page 36*)

A Valuable Adjunct to Volume I

Wood Chemistry, 2nd Edition, Volume II. Edited by Louis E. Wise and Edwin C. Jahn. Reinhold Publishing Corp., New York (1953). 595 pp., $15.00.

Reviewed by John B. Calkin, Consultant, New York.

The purposes of the ACS Monographs, i.e., a thorough treatment of a selected field for correlation with other areas, and to stimulate further research in the same sphere, are exemplified in this work. The contributors to the Monograph are well known and respected by the scientific and technical community as a whole.

Volume II is divided into four parts dealing with surface properties of cellulosic materials, industrial wood chemistry, decomposition of wood by microorganisms and the chemical analysis of wood. Surface properties by Dr. Stamm covers adsorption of gases, water vapor, nonaqueous vapors, from solution, and other properties.

The section on industrial wood chemistry is covered by a number of authorities from the academic and the industrial fields. The work covers thermal properties, wood hydrolysis, delignification (pulping) and bleaching.

Decomposition of wood, by Dr. W. G. Campbell, is written from the biological point of view. The part on chemical analysis is by Dr. B. L. Browning and covers determination of fractions of wood, lignin and miscellaneous determinations. The subject of analytical data and their significance is covered by Dr. Browning and Dr. I. H. Isenberg.

The editors are to be complimented for bringing forth a readable, coordinated, ready reference work.

The present reviewer regrets the absence of an author index.

As is usual, each reviewer finds some part, or parts, of a work which could in his judgment be treated more adequately. The present situation is no exception. Some of the more recent references to sorption of alkalies should have been included. The present reviewer considers the treatment in Heuser's "Cellulose Chemistry" and Marsh & Wood's "An Introduction to the Chemistry of Cellulose" more adequate. Such may also reflect differences in judgment between authors and between authors and reviewers on importance and space allotment.

The book is recommended highly and should be studied as needs arise. It is well worth having along with Volume I.

Book of Principles and Facts

Inorganic Chemistry: An Advanced Textbook. Therald Moeller. John Wiley & Sons, Inc., New York (1952). 966 pp., $10.00.

Reviewed by W. A. Selke, Assistant Professor, chemical engineering, Columbia University, New York, N. Y.

Most of us had our only formal study of inorganic chemistry as part of first-year general-chemistry courses and courses in qualitative analysis. The oversimplifications employed at these levels sometimes leave us unprepared for the increasing number of problems in which these simplifications are not valid. The compendium by Mellor can often be of aid for occasional reference, but does not answer the need for a book from which principles, as well as facts, can be learned. "Inorganic Chemistry" by Moeller fills these requirements more than adequately.

The author divides his book into two parts. The first, general principles; the second, the properties of the elements. The part devoted to principles includes chapters on atomic nuclei; the extranuclear structure of the atoms; the periodic classification of the elements, characteristics dependent on the extranuclear structure, including valency and the chemical bond; complex ions and coordination compounds; oxidation-reduction potential; acids and bases; and nonaqueous solvents. In each of these chapters the historical development of the current theories is presented in a manner, which is not only intelligible but also pleasurable to read. Some of the subject matter will be unfamiliar to chemical engineers who left school more than a few years ago, but it can be understood without supplementation. It might be argued that some of these topics would be more appropriate material for a book on physical chemistry or chemical bonds, yet, the applicability to inorganic-chemistry problems makes it desirable to include the material here.

The part dealing with the chemical elements takes up the various periodic groups in separate chapters. Some engineers might be disappointed to find how little space is devoted to the process technology of these elements. In fact, first-year general-chemistry books frequently contain more on this subject. This lack, however, is understandable because the volume is already so large that inclusion of additional material available elsewhere is not desirable.

An ample subject index of 27 pages, and an author index extend the utility of the text as a reference work.

One of the shortcomings of this book, which is common to most textbooks on extensive subjects, is that some of the material does not reflect the latest advances in those fields. This limitation would be of minor concern, however, to the majority of the users and readers of the book.

Not only as a reference work, but as a book in which one might enjoy more extended readings, Moeller's book deserves a place in the chemical engineers' bookcase.

Answer to Chemical Researcher

Radioisotopes in Industry. John R. Bradford, Reinhold Publishing Corp., New York (1953). 309 pp., $8.00.

Reviewed by Bernard Manowitz, Brookhaven National Laboratory, Upton, L. I., N. Y.

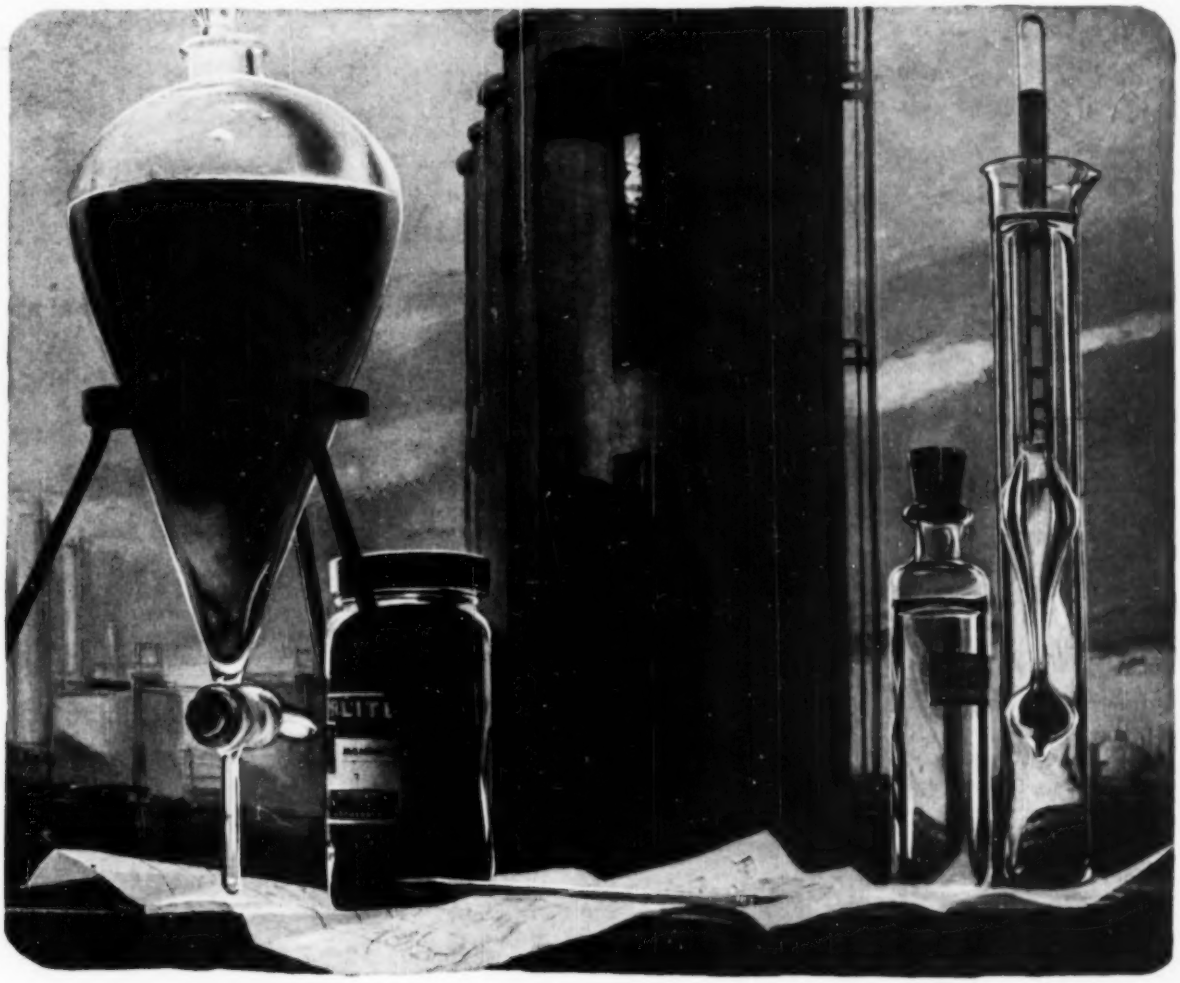
Based on a series of lectures given at Case Institute of Technology in April, 1951, this book is essentially a compilation of the papers presented by fourteen contributors. The book contains a wealth of information on the application of radioisotopes and on many other related topics, but, unfortunately, its format limits its usefulness. The administrator and research director patient enough to wander through much repetitious matter will gain an insight into the scope and policies of the radioisotope program of the Atomic Energy Commission and into the limitations and capabilities of the A.E.C.'s isotope production and separation facilities. He will be exposed to myriads of ideas on the applications of radioisotope techniques, and possibly will find that this new research tool offers a means of solution to many of his own hitherto unanswerable chemical research problems, an opportunity to better evaluate his process and product, and a unique aid in new product research. Management personnel will be introduced to the problems of radio chemical laboratory design, decontamination, and waste disposal, but will get little or no information on costs.

The design engineer will find that the work contains a maze of esoteric information, but should be able to grasp enough of the principles in Donald R. Ward's excellent chapter "Design of Laboratories for Safe Use of Radioisotopes" to evaluate the requirements of a radiochemical laboratory at his own plant site.

The research engineer or chemist also will find that there are a limited number of chapters of direct interest to him. The sections on fundamentals are brief and contain hardly more information than one would expect to get in an hour's lecture on an unfamiliar subject. However,

(*More Marginal Notes on page 58*)

NEW STANDARDS OF CHEMICAL PURITY



C. P. reagents are fine for laboratory use, but they can get you into trouble. They often lead you to overlook the impurities in the chemicals of commerce, which may upset carefully calculated reaction rates and yields.

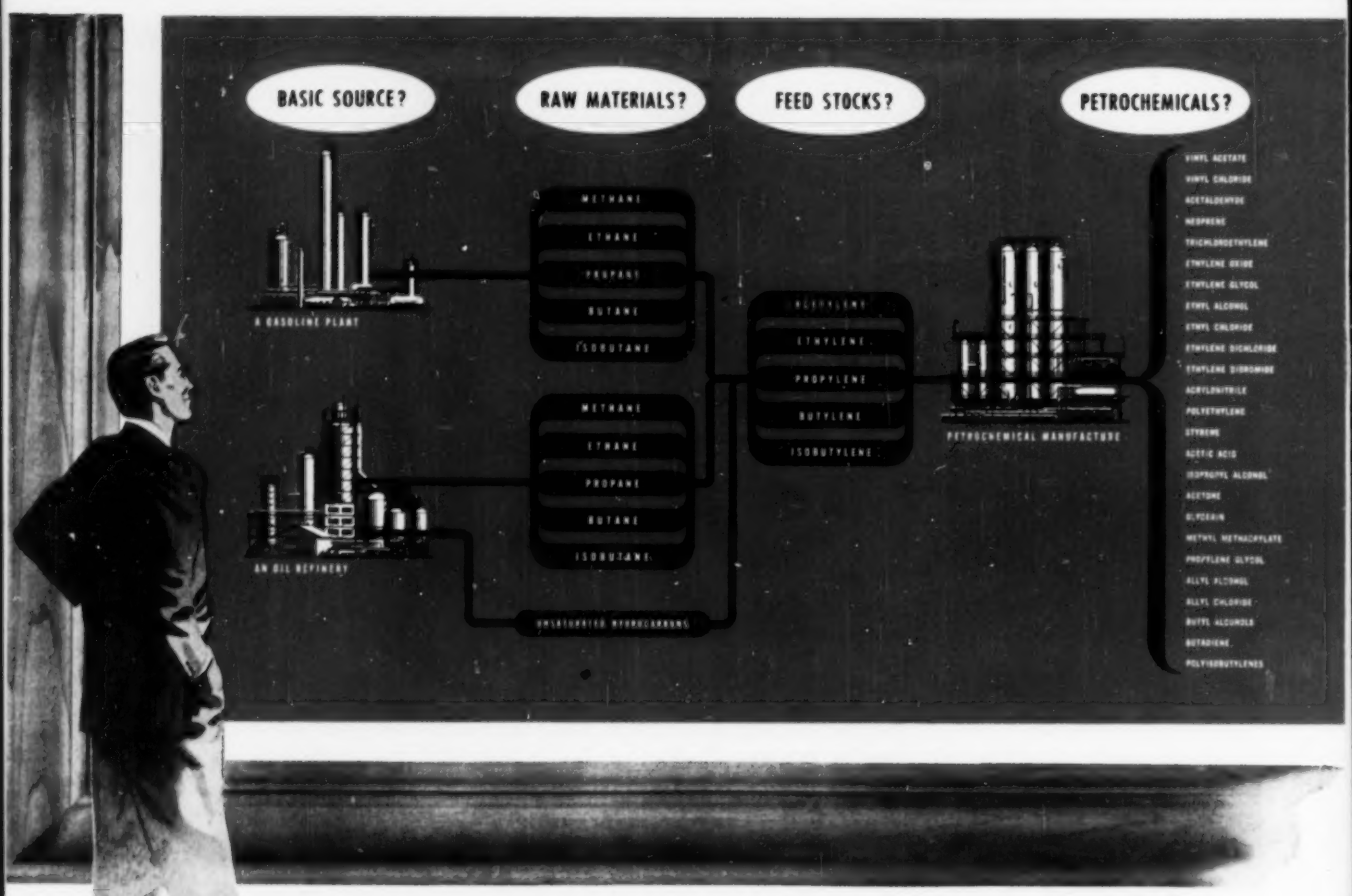
There is at least one chemical—glycerine—where you can forget this problem. The manufacturers now can supply a C.P. grade in tank cars. They do it by passing crude glycerine through a series of AMBERLITE® cation and anion exchangers, and it comes out essentially pure. Concentration by simple evaporation makes it ready for shipment.

AMBERLITE ion exchange seeks jobs like this. It has found them in processing glycerine, sorbitol, sugar, syrups, arabic acid, formic acid, acetone, formaldehyde, metals, and milk. If your process is hampered by trace quantities of chemical impurities, investigate AMBERLITE ion exchange as a means of disposing of them.

AMBER-HI-LITES, *a bi-monthly report on ion exchange, is available on request.*

ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION PHILADELPHIA 5, PENNSYLVANIA



Where do you fit in this petrochemical picture?

Currently engaged in this highly specialized work, Fluor can help determine your potentials in this rapidly expanding industry.

Petrochemicals, the largest new factor in our ever-expanding world of chemicals, now account for nearly one-quarter of all U. S. chemical production. Despite this, it is estimated that only one-half of one percent of all present oil and gas production is being utilized as petrochemical feed stock. This opens up new opportunities for the oil and gas producer and investor.

If you own, operate, or have interests in an oil refinery or a gasoline plant, you should be aware of *your* potential as a supplier of petrochemical raw materials. This is particularly so when it is considered that the increase in value of an end petrochemical product may easily be four or five times greater than that of normal products realized from other hydrocarbon processing operations!

Let Fluor assist you...

The proven abilities to design, engineer and construct complete plants and facilities for the petroleum, natural gas and petrochemical industries have established The Fluor Corporation as one of the nation's major engineering and construction organizations.

One call to Fluor will place men with broad and diversified experience in petroleum and chemical engineering technology and economy at your disposal. Let Fluor put these talents and facilities to work for you. You will be sure with Fluor!

BE SURE WITH

FLUOR

THE FLUOR CORPORATION, LTD.
LOS ANGELES 22, CALIFORNIA

FOREIGN: FACTS-FLUOR, PARIS
FLUOR OF CANADA, TORONTO
FLUOR INTERNATIONAL, BEIRUT
MEAD WRIGHTSON, LONDON

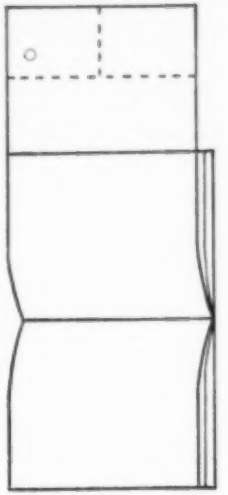
ENGINEERS
CONSTRUCTORS
MANUFACTURERS

NEW YORK
CHICAGO
PHILADELPHIA
BOSTON
PITTSBURGH
SAN FRANCISCO
HOUSTON
BIRMINGHAM
TULSA

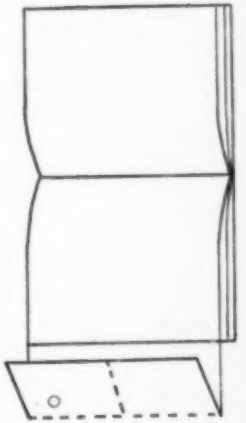
for. your information

Here is a new information service—a convenient way to get the chemical engineering information you need on new equipment, on advertised products, on the newly announced developments reported on these pages. A one post card inquiry designed to bring data quickly and easily. Circle the items of interest, sign your name, position, address, etc., and drop in the mail.

Just a moment is needed to learn how to use this insert. When looking through the front part of the magazine pull the folded portion of the insert out to the right, and the numbers on the post card are convenient for marking. THEN . . . .



as you pass the pull-out page, and it is on the left, fold the post card back along the vertical scoring, and once again the numbers are handy for circling.



Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 48890, Sec. 34.9, P. L. & R., New York, N. Y.

CHEMICAL ENGINEERING PROGRESS
120 East 41st Street
New York 17,
New York

Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 48890, Sec. 34.9, P. L. & R., New York, N. Y.

CHEMICAL ENGINEERING PROGRESS
120 East 41st Street
New York 17,
New York

PRODUCTS

IFC **Activated Carbon**
The use of activated carbon to recover solvents in a variety of industries. Booklet.
Carbide & Carbon Chemicals Co.

3R **Pilot Plant Sifter**
Rotary motion sifter with interchangeable platform for flask agitation.
B. F. Gump Co.

4L **Oil Reclaimer**
A unit for cleaning lubricating oils, sealing oils from vacuum pumps, etc. Bulletin.
The Hilliard Corp.

5A **Steel Plate Fabrication**
Fabrication of tanks, pressure vessels, etc., from steel plate.
Posey Iron Works, Inc.

6L **Mixers**
Spiral ribbon mixers used to prepare filter cake for shipment.
Read Standard Corp.

7A **Cooling Towers**
Cooling towers, atmospheric sections and Solo-aire units for process industries.
Hudson Engineering Corp.

9A **Dowtherm**
New technique for alternate heating and cooling in the same equipment.
Dow Chemical Co.

10T **Special Equipment**
Design development and manufacturing of process equipment.
Artisan Metal Products, Inc.

10B **Poro-Stone Filter**
Packaged filter plants with permanent filter media. Bulletin 431.
R. P. Adams Co., Inc.

11A **Graphite Anodes**
For use in the electrolytic industry.
Great Lakes Carbon Corp., Electrode Division.

12L **Liquid Oxygen Pump**
Special pump to operate at —297.4° F. Bulletin 203-6.
Lawrence Pumps, Inc.

13A **Liquid Oxygen**
Liquid Oxygen and Nitrogen Transport Unit.
Hofman Laboratories, Inc.

14L **Blender**
21-ton unit which mixes 1000 gal. at once.
Baker Perkins, Inc.

15A **Ammonium Nitrate Plant**
Ammonia, ammonium nitrate, and nitrate acid plants at pressures up to 15,000 lb./sq.in.
Girdler Co.

16A **Glassed Steel Reactors**
Capacities of 5 to 3500 gal., pressures as high as 200 lb./sq.in. Bulletin 894-F-2.
The Pfaudler Co.

332A **Dryers**
Custom designed and tested dryers.
Louisville Drying Machinery Unit, General American Transportation Corp.

19A **Pressure Filters**
Filter for vacuum or pressure operation, or combination of the two.
The Eimco Corp.

21A **Controllers**
Process controls for temperature, pressure, and flow of reactants as preset by the operator.
The Foxboro Co.

23A **Valve Lubricant**
Lubricant for Nordstrom valves in various services.
Rockwell Manufacturing Co.

25A **Tank Filter**
Quick opening retractable tank filter 100 to 2000 sq. ft. filtering area.
Sparkler Manufacturing Co.

26A **Graphic Panels**
For process control centralized graphic instrumentation.
Minneapolis-Honeywell Regulator Co.

28A **Vacuum Crystallizer**
Krystal units for uniform noncaking, dust-free crystals. Bulletin 50-A.
Struthers Wells Corp.

31R **Low-Temperature Equipment**
Facilities for extreme low-temperature research. Bulletin CEP 22-4.
Arthur D. Little, Inc.

32L **Valves**
20,000 different standardized valve assemblies. Catalog V-52.
Hills-McCanna Co.

33R **Gaskets**
For corrosion and contamination problems Chemiseal Teflon-Jacketed Gaskets. Catalogs.
United States Gasket Co.

34A **Pyrex Pipe**
Glass pipe of high chemical stability and easy cleaning for process industries.
Corning Glass Works

37A **Karbate**
Impervious graphite fittings, heat exchangers, pumps, etc. Catalogs.
National Carbon Co.

39A **Ion Exchangers**
Cation and anion exchangers for process industries.
Rohm & Haas Co.

40A **Petrochemicals**
The design, engineering and construction of complete plants for petroleum, natural gas and petrochemical industries.
The Fluor Corp., Ltd.

49A **Spray Dryers**
Illustrated booklet of twenty-one recent Bowen spray dryer installations.
Bowen Engineering, Inc.

50L **Demineralizing**
New technique of mixed-bed demineralization.
Barnstead Still & Sterilizer Co.

51A **Filter Aid**
Celite diatomaceous earth in nine standard grades. For filtration of waste waters.
Johns-Manville

Chemical Engineering Progress

Numbers followed by letters indicate advertisements, the number corresponding to the page carrying the ad. This is for ease in making an inquiry as you read the advertisements. Letters indicate position—L, left; R, right; T, top; B, bottom. A indicates a full page; IFC, IBC, and OBC are cover advertisements.

Be sure to give name, address, position, etc.

Remember, the numbers on the upper portion of the card bring you data on only the bulletins, equipment, services, and chemicals reported in these information insert pages. The lower portion of the card is for the advertised products, and is keyed not only to advertising pages, but also to the memory-tickling list under the heading Products.

52L **Tube Ends**
Replacement tube inlets of heat exchangers to increase effective tube life. Booklet.
Condenser Service & Engineering Co.

52R **Spray Nozzles**
Spray-nozzle design adapted to the character of the liquid being sprayed. Catalogs.
Spraying Systems Co.

53A **Nickel Alloys**
Alnico alloys utilized throughout industry.
The International Nickel Co., Inc.

54L **Furane Resin Cement**
Furane resin cement as a mortar for acid-proof masonry.
Delrac Corp.

55A **Density Transmitter**
Continuous density measurement at line pressures to 300 lb./sq.in. gauge of flowing liquids. Date Book 1004.
Republic Flow Meters Co.

57A **Crystal Dehydration**
Centrifugal dehydrators engineered to withstand severe operating conditions. Bulletin No. 1257.
The Sharples Corp.

58L **Cone Blender**
Twin Cone Blenders for homogeneous dry blending. Catalog V.
Paul O. Abbe, Inc.

59A **Chemical Pump**
Triplex Pump for nitric acid; 185 lb./min. against 400 lb./sq.in. maximum pressure. Data sheets.
The Aldrich Pump Co.

(Continued on back of this insert)

Please do not use this card after December, 1953

1	2	3	4	5	6	7	8	9	10	11	12	15	16
17	18	19	20	21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40	41	42	43	44
45	46	47	48	49	50	51	52	53	54	55	56	57	58
59	60	61	62	70	71	72	73	74	75	76	77	78	79
80	81	82	83	84	85	90	91	92	93	94	95	96	97
98	99	100	101	102	103	104	105	106	107	108	109	110	111
112	114	115	116	117	118	119	120	121	122	123	124	125	126
127	128	129	130	131	132	133	134	135	136	137	138	139	140
141	142	143	144	145	146	147	148						

Advertisers' Products

IFC	3R	4L	5A	6L	7A	9A	10T	10B
11A	12L	13A	14L	15A	16A	332A	19A	21A
23A	25A	26A	28A	31R	32L	33R	34A	37A
39A	40A	49A	50L	51A	52L	52R	53A	54L
55A	57A	58L	59A	60L	61A	63A	64L	65A
66L	67R	68L	69R	71L	71R	73T	73B	75R
77T	77B	78L	79T	79B	IBC	OBC		

Chemical Engineering Progress Data Service

Name .....

Company .....

Position .....

Address .....

City .....Zone .....State .....

☐ I want a subscription. Bill me $6.00 for a year.

Please do not use this card after December, 1953

1	2	3	4	5	6	7	8	9	10	11	12	15	16
17	18	19	20	21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40	41	42	43	44
45	46	47	48	49	50	51	52	53	54	55	56	57	58
59	60	61	62	70	71	72	73	74	75	76	77	78	79
80	81	82	83	84	85	90	91	92	93	94	95	96	97
98	99	100	101	102	103	104	105	106	107	108	109	110	111
112	114	115	116	117	118	119	120	121	122	123	124	125	126
127	128	129	130	131	132	133	134	135	136	137	138	139	140
141	142	143	144	145	146	147	148						

Advertisers' Products

IFC	3R	4L	5A	6L	7A	9A	10T	10B
11A	12L	13A	14L	15A	16A	332A	19A	21A
23A	25A	26A	28A	31R	32L	33R	34A	37A
39A	40A	49A	50L	51A	52L	52R	53A	54L
55A	57A	58L	59A	60L	61A	63A	64L	65A
66L	67R	68L	69R	71L	71R	73T	73B	75R
77T	77B	78L	79T	79B	IBC	OBC		

Chemical Engineering Progress Data Service

Name .....

Company .....

Position .....

Address .....

City .....Zone .....State .....

☐ I want a subscription. Bill me $6.00 for a year.

PRODUCTS *(Continued)*

60L **Valves**
Single-disc and double-disc valves with special flat surfaces. Bulletin 332-F.
Okadee Co.

61A **DorrClones**
Classification features of the DorrClone in cement manufacture. Bulletin 2500.
The Dorr Co.

63A **Drying Research**
Drying service to determine the best commercially practical way to dry a product.
C. G. Sargent's Sons Corp.

64L **Chemical Pump**
Eco all-Teflon and stainless steel pump for lab., pilot plant and small volume pumping.
Eco Engineering Co.

65A **Diaphragm Valves**
Case history of diaphragm valves in alcohol solution antifreeze fill lines to automobile radiators.
Crane Co.

66L **Impervious Graphite Pump**
Corrosion-resistant chemical pump of Impervite.
Falls Industries, Inc.

67R **Spun Alloy Equipment**
Duraspun Centrifugal Casting 12-14% chromium equipment, pipe or tubing, odd shaped pieces. Catalog 3150.
The Duraloy Co.

68L **Resistant Fabrics**
For dust collection, hot or corrosive materials. Samples.
Filtration Engineers, Inc.

69R **Valves and Fume Ducts**
Haveg corrosion-resistant plastic pipes which can withstand temperatures up to 265° F. Bulletin F-6.
Haveg Corp.

71L **Mist Eliminators**
Removal of liquid carry-over by using pads made from multiple layers of knitted wire mesh. Bulletin.
Metal Textile Corp.

71R **Antifoam**
Use of antifoams to increase production. Use coupon for samples.
Dow Corning Corp.

73T **Crushers**
Intermediate crusher for experimental labs, pilot plants, and test runs. Catalog.
American Pulverizer Co.

73B **Steam Traps**
Used to reduce the heating cycles of kettles. Bulletin 152.
W. H. Nicholson & Co.

75R **Nitric Acid Process**
Low-pressure ammonia conversion process for making nitric acid.
General Industrial Development Corp.

77T **Plasticizer Oil**
A low-gravity, high-boiling plasticizer for rubber compounding.
Pan American Refining Corp.

77B **Agitator Drives**
Heavy duty vertical, triple reduction drive units.
Western Gear Works.

78L **Process Equipment**
Continuous rotary dryers, kilns, and coolers. Bulletin 16-D-40.
Hardinge Co., Inc.

79T **Wood Sole Shoes**
Shoes for those who work with chemicals, acids, salts, oils, water, etc. Catalog.
Stahmer Shoe Co.

79B **Jet Cooling**
Steam-jet vacuum unit which flash-cools water and other liquids to 32° F.
Croll-Reynolds Co., Inc.

IBC **Controlled Volume Pumping**
Air-powered pumps for chemical proportioning systems.
Milton Roy Co.

OBC **Fluid Mixing**
Fluid mixing, blending, or circulating operation for all chemical processes. Catalogs.
Mixing Equipment Co., Inc.

EQUIPMENT

1 **Pillow Blocks.** Two types of pillow blocks from W. A. Jones Foundry and Machine Co. spherical and cylindrical units, expanding and nonexpanding.

2 **Analytical Balances.** Brochure on care and use of analytical balances from Christian Becker Division of Torsion Balance Co.

3 **Infrared Absorption Cells.** Standard liquid, solid, gas, and special infrared absorption cells of Perkin-Elmer Corp. Also information on pressure, variable space, and rotable cells.

4 **Fork Lift Trucks.** Gas and electric-powered fork-lift trucks, attachments and devices included in catalog from Clark Equipment Co. Capacities 1000 to 15,000 lb.

5 **Temperature Indicator.** Leeds & Northrup Co. Speedomax electronic console indicator permits operator to scan up to 200 thermocouple temperatures as rapidly as he can log.

6 **Stainless Steel Filters.** Porous stainless filters having doubled tensile strength, 25,000 lb./in., smooth surface, controlled thickness. Tolerances maintained to ±.002 in. Pore opening 10μ on .040 in. thickness. Micro Metallic Corp.

7 **Engineering Data.** Entitled Desk Calculator, six-page pocket-size folder presents formulas, constants, and conversion factors for use in basic engineering, dust-control calculations, etc. Pangborn Corp.

8 **Humidity Control.** For control of relative humidity in air conditioning, a control from Niagara Blower Co. Data sheet includes schematic drawing, operating principle.

9 **Weight Recorder.** Mechanoprint mechanical weight recorder. Howe Scale Co. Built as part of tape-drive dial head. Touch of push bar prints weight. Accuracy 1/10 of 1% of dial chart capacity.

10 **Steam Trap.** Side inlet-side outlet steam trap from Armstrong Machine Works, with 1 or 1¼-in. threaded connections. Capacities to 6,800 lb./hr.; pressure range 0 to 250 lb./sq.in.

11 **Liquid-Tight Conduit.** Flexible liquid-tight electric wiring conduit from American Brass Co. Flexible galvanized steel core, synthetic cover. Protects wiring against moisture, dirt, chemicals, corrosive fumes.

12 **Pneumatic Atomizing Nozzles.** Large capacity pneumatic atomizing nozzles from Spraying Systems Co. Pressures 6 to 90 lb./sq.in.; capacities 4 to 20 gal./min.

15 **Teflon-Faced Steel.** Teflon cemented to steel plate and with studs for attachment to conveyors. Reduces product and package damage from adherence and abrasion. Available in sections to 36 in. long, or as required. United States Gasket Co.

16 **Centrifugal Suction Pump.** For pumping water, solvents, brines, etc., end suction centrifugal pump from Warren Steam Pump Co., Inc. Capacities to 1000 gal./min., heads to 400 ft.

17 **Blenders, Mixers.** Gemco blenders and Muench mixers from General Machine Company of New Jersey. Leaflet discusses blending and mixing, materials handled.

18 **Oil Reclaimer.** Hyflow oil reclaimers for removing contaminants in lubricating or industrial oils. Units to 500 gal./hr. Hilliard Corp.

19 **Dynel Fabrics.** Wall chart tabulating effect of specific chemicals on Dynel fabric after 20-hr. immersion. Carbide and Carbon Chemicals Co.

20 **Relief Valves.** Handbook on temperature and pressure relief valves from A. W. Cash Valve Mfg. Co. Sections on purpose, location, types, do's and don'ts, codes.

21 **Magnetic Drive Pump.** Magnetically driven, combined motor and centrifugal pump, requiring no mechanical seal or stuffing boxes. For handling corrosive, radioactive, and highly volatile fluids. Capacities to 150 gal./min., pressures to 150 lb./sq.in.; sizes 1/3 to 3 hp. Folder from Chempump Corp.

22 **Spectrometers.** Analytical instruments and spectrometers for science and industry by Consolidated Engineering Corp. Bulletin gives pertinent information.

23 **Mechanical Seals.** Garlock Packing Co. O ring mechanical seal for corrosive use. Unbalanced for pressures to 200 lb./sq.in.; balanced over 1,000 lb./sq.in. Of Teflon, Buna-N, neoprene, or silicone.

24 **Potentiometer.** A sub-miniature wire-wound potentiometer from Bourns Laboratories. Settings maintained during shock, vibration, acceleration. Resistances 250 to 10,000 ohms.

25 **Selector Switch.** Development of Cleaver Brooks Co. permits changeover from gas to oil or vice versa in company's combination gas- and/or oil-fired boilers.

26 **Environmental Test Unit.** Multipurpose environmental test unit introduced by Murphy & Miller, Inc. provides wide range of temperature, vacuum and humidity conditions. For laboratory or production testing.

27 **Porcelain Valve.** Valvrator, a porcelain diaphragm air motor valve from Fischer & Porter Co. Safety armored, affords protection against thermal or physical shock; permits control of corrosive liquids and gases. Sizes for pipe ½ to 2 in. Cutaway views.

28 **Demineralizers.** Automatic mono-column demineralizers from Penfield Mfg. Co., Inc. Performance data, schematic drawing, specifications. Cation and anion exchangers in single tank.

29 **Agitated Water Bath.** Magni-Whirl water bath by Blue M Electric Co. eliminates stirrers and circulating systems. Provides agitation magnetically in all areas of liquid mass. Microtrol selects and repeats two most-used temperatures.

30 **Oscillograph.** Portable six-channel oscillograph from Brush Electronics Co. Sight glass permits view of chart during recording.

31 **Bulk Packer.** Bulk packer, Richardson Scale Co., automatically weighs and delivers bulk chemical or food products.

32 **Condensifilter.** Disposable filter cartridges for Hankinson Corp. condensifilter. Replaced by removing one nut. Shutdown and maintenance savings.

33 **Fluidometer.** Automatic metering system for batching light or heavy liquids. Hetherington & Berner, Inc. Measures gallons to carload lots. Schematic drawing of system, illustrations, other data.

34 **Dry Box.** For handling radioisotopes and radioactive materials, stainless steel low intensity dry box from S. Blickman, Inc. Also for bacteria, viruses, poisons. Leaflet lists specifications, general description.

35 **Sound Measurement.** All phases of sound-measuring equipment and accessories are covered in bulletin from General Radio Co.

36 **Synthetic Pipe.** American Hard Rubber Co. Tempron, heat and chemical resistant synthetic hard rubber. Material is rigid. Available as sheet, rod, tubing, pipe fillings, and molded parts.

37 **Control Valve.** Combination automatic and manual control valve announced by Annin Co. Uses Domotor control unit plus handwheel. Pressures to 5000 lb./sq.in. to 50,000 lb./sq.in. for special applications.

38 **Pressure Switch.** Six classes of pressure switches, proof pressures 500 to 12,000 lb./sq.in. For liquid, gas, or water systems. Barksdale Valves.

39 **Vibrator.** A 2-in. piston diameter air vibrator from Cleveland Vibrator Co. to eliminate arching and sticking in bins, chutes, handling granular materials. Portable. One unit can service several bins.

40 **pH Chart.** From R. P. Cargille Laboratories, Inc. a reference chart for selection of test papers for entire pH scale.

41 **Vacuum Fittings.** Swagelok tube fittings from Crawford Fitting Co. Provide vacuum-tight mechanical seal and form ultrahigh vacuums.

42 **Wash Fountain.** Haws Drinking Faucet Co. goggle-wash fountain for shop and laboratory workers permits easy cleaning of goggles, face shields, safety glasses. Foot operated.

43 **Manostat.** For pressure control in laboratory, pilot plant, and industry. Cartesian manostat from Emil Greiner Co.

44 **Adjustable Drive.** All electric adjustable-speed drive of ¾ to 3 hp. announced by Reliance Electric & Engineering Co. For processing units, including chain and belt conveyors; rotating filters; mixers; centrifuges.

45 **Valve Lubricant.** Flat-top gun and long-spouted bulk lubricant tubes by Rockwell Mfg. Co. for lubrication of Nordstrom valves of all sizes. Available in packages of six; eight types of lubricant.

46 **Vapor-Tite Valve.** Johnston & Jennings Co. introduces Vapor-Tite membrane seating conservation regulator. Leakproof, Buna N membrane is flexible. Folder shows cutaway view, dimensions, weights.

47 **Corrosion Resistant Tanks.** Tanks fabricated from unplasticized polyvinyl chloride from American Agile Corp. Resistant to 170° F. Custom built, light weight, strong.

48 **Welding Electrodes.** Stainless steel arc welding electrodes from Metal & Thermit Corp. in hermetically sealed metal cans. Variety of types.

49 **Plastic Pipe.** Flexible plastic pipe for drainage, sewage disposal, irrigation, by Johnston Plastic Corp. From ½ to 6 in. diameter; lengths 500 ft. for ½ in., 125 ft. for 3 in. sizes. Corrosion-proof.

50 **Rubber Linings.** For tanks, drums, pipes, and valves, rubber linings from Metalweld, Inc. Protects from thermal and mechanical shock. Abrasion, chemical and temperature resistant. Bulletin lists resistant characteristics, shows welding process.

51 **Rotary Gear Pump.** Simplified rotary gear pump from Sier-Bath Gear & Pump Co. for positive displacement of lubricating liquids. Handles fluids and semi-fluids 32 to 250,000 s.s.u.; capacities 1 to 500 gal./min.

52 **Carbon Rods.** High-purity spectrographite rod for chemical and metallurgical analysis by spectrography announced by Stackpole Carbon Co. Less than .001% impurities. Lengths to 12 in., diameters ⅛ to 5/16 in. Catalog.

53 **Liquid-Level Control.** Single-thyratron electric liquid-level control for process industries operates without radio frequency from single capacitive probe. Thermo Instruments Co.

54 **Multimotor Unit.** Unit from U. S. Electrical Motors, Inc., consisting of horizontal motor, footless right-angle, worm-gear motor and overrunning clutch, for powering machinery, etc.

55 **Drum Clamp.** Combination carton and drum clamp for use without skid or pallet on fork trucks of Elwell-Parker Electric Co.

56 **Filters.** From Ertel Engineering Corp. filter employing neither rubber washers nor gaskets around filter frame. Meets any filter requirement from pre- to ultrafine filtration. Filter medium forms seal around edges of filter frame, thereby prevents liquid loss. Sizes hold from 10 to 100 16 in. filter surfaces. Leaflet.

57 **Torque Converter.** Two-stage torque converter from Twin Disc Clutch Co. for industrial hydraulic drives. Develops up to 4:1 torque multiplication. Several types.

58 **Ice Machine.** Ajax Corp. of America announces pebble ice machine. Three sizes 200, 400 or 800 lb./day. Requires but one sq.yd. floor space; 39 in. high.

59 **Oxygen Container.** Semitrailer mounted liquid-oxygen container from Hofman Laboratories, Inc. Capacity 8 to 12 ton. Vacuum maintained 150μ. Motor transfers 100 to 150 gal./min. against 40 lb./sq.in gauge.

60 **Centrifugal Pumps.** Corrosion-resistant sanitary and industrial centrifugal pumps from Tri-Clover Machine Co. Illustrated leaflet. For food, chemical, dairy industries. Sizes 1800 and 3600 rev./min.

61 **Teflon Parts.** Molded diaphragms, spiral washers, discs, seals, stock rods, tubing, sheeting produced out of Teflon by Sparta Heat Treat Co.

62 **Valve Control.** An electric contact controller for solenoid valves, warning signals and motors by H. O. Trerice Co. Vapor actuated, can stand heavy electrical load. Pilot lights show position of switch.

CHEMICALS

70 **Solvents.** Monsanto Chemical Co. announces two high boiling solvents, phenylcyclohexane and bicyclohexyl. Used as "compatibilizing" and penetrating agents. Both colorless oily liquids. Suggested for herbicide formulae or perfume.

71 **Aniline.** From National Aniline Div., Allied Chemical & Dye Corp., the story of aniline, the first synthetic organic chemical. Describes present uses and future possibilities.

72 **Chemical Resistance Table.** Single page chemical resistance table. Laminex Corp. Lists acids, alkalies, various salts, gases, organic materials, etc.

73 **Waterproof Adhesives.** Penacolite resorcinol adhesives for permanent waterproof bonding covered in booklet from Koppers Co., Inc. Uses, temperature ranges, types, etc.

74 **N-Phenylmaleamic Acid.** Experimental chemical from American Cyanamid Co. n-phenylmaleamic acid, available in trial-lot quantities. Yellow, crystalline, shows promise for preparing resins, synthetic fibers, plastics, or as an intermediate in synthesis.

75 **Organic Chemicals.** Solvents, industrial chemicals, resins, plastics, from Shell Chemical Corp. Listed and described in a 100-page catalog. Special section on anhydrous ammonia fertilizers.

76 **Sugar Cane Wax.** Sun Chemical Corp., Duplicane 517, a sugar cane wax for carbon-paper and business-forms industries. Maintains hardness, better disperses and dissolves all types of dyestuffs and toners used in carbon paper.

77 **Chlorinating Compound.** Halane from Wyandotte Chemicals Corp. A stable chlorinating compound containing 66% by weight available chlorine. Loses 2% chlorine after storage at 140° for fourteen weeks. Data sheets.

78 **Flotation Agents.** Revised edition of technical book on Hercules Powder Co.'s flotation agents. Section on shipping information describes type, per cent concentration weight, etc. Uses, functions, formulae.

79 **Polyester Resins.** Bakelite Co. booklet gives information on production methods, formulations, properties of polyester resins. Information on compounding, reinforcing materials, mold release agents, fabrication of reinforced plastics.

80 **Methanol.** Brochure on methanol from Commercial Solvents Corp. Contains general descriptive material on use, toxicology, test methods. Also charts and tables on physical properties and mixtures.

81 **High Boiling Phenols.** Available in tank car quantities, high boiling phenols from Carbide & Carbon Chemicals Co. Product is semirefined mixture of short-chain alkyl-substituted phenols with distillation range of 230° to 270° C.

82 **Ion-Exchange Resin.** Descriptive information, flow sheets contained in bulletin from Chemical Process Co. on Chempro C-20, a polystyrene cation exchange resin. Data on application.

83 **Nylon Molding Powders.** Use of nylon molding powders by industrial engineers described and illustrated in booklet from Polychemicals Dept. Du Pont Co., Inc. Covers thirty case histories.

84 **Water Softeners.** Bulletin from Graver Water Conditioning Co. on principles and details of sodium and hydrogen cycles of zeolite water softeners. For engineers of power, chemical, industrial process plants.

85 **Teflon.** From Polymer Corporation of Pennsylvania, technical data on Teflon. Applications, properties, characteristics, etc.

BULLETINS

90 **Shipping Guide.** Packaging guide for use of multiwall paper shipping sacks from Bemis Bros. Bag Co. Sections on storage, filling and closing, proper handling, etc.

91 **Tank-Trailers.** Single and tandem axle tank-trailers from Fruehauf Trailer Co. for transporting propane, butane, acids, latex, asphalt, etc.

92 **Salt.** From International Salt Co., Inc. a pictorial history of salt, how mined, varieties, uses in agriculture, industry, medicine. Packaging methods, etc.

93 **Torque Motors.** For maxium-rated torque without damage to windings, torque motors from Howell Electric Motors Co. Loose-leaf bulletin on applications, sizes, and ratings.

94 **Temperature Testing.** Low-temperature industrial freezers, also complete temperature-range-testing units by Industrial Freezer Division, Webber Appliance Co., Inc. temperature to —165° F., heat range to +350° F. Twelve models.

95 **Pigment Handbook.** Loose-leaf binder from C. K. Williams & Co. covers line of oxides, siennas, umbers, etc. Color samples, technical reports, price lists.

96 **Duafuel Engines.** Heavy-duty Diesel engines, gas and Duafuel, built by Nordberg Mfg. Co. Duafuel operates on oil or gas; sizes 10 to more than 10,000 hp. Construction details, installation views, schematic diagram.

97 **Resistance Welding.** Ampco Metal, Inc. catalog includes new tips and holders recently added. Reference tables, comparative charts of physical properties, applications, specification data, etc.

98 **Totally Enclosed Motors.** Illustrated three-color bulletin from U. S. Electrical Motors, Inc. on totally enclosed motor. With fan to 75 hp.; without fan from ¼ to 2 hp., hi-draft ventilation, removable cover, streamlined housing, sealed terminal..

99 **Industrial Controls.** Catalog of nonindicating electric, electronic, and pneumatic controllers for temperature, pressure, humidity. Minneapolis-Honeywell Regulator Co. Specifications, dimensions, drawings, application data.

100 **Insulation Service.** From Johns-Manville, handbook on complete insulation service for chemical process plants and oil refineries. Contains sections on specifications, recommendations for various types, tables, illustrations.

101 **Houdriflow Operations.** House organ of Houdry Process Corp. records two years of commercial Houdriflow operation. Covers design features, tables, cutaway views, etc.

102 **Stainless Products.** Schnitzer Alloy Products Co. catalog conveniently tabbed for easy reference on complete line of stainless fittings, screws, tubings, nuts, etc.

103 **Solenoid Valves.** Built for standard pipe connections in sizes ⅛ to 1¼ in., rotating disc construction. For operating air or hydraulic cylinders, valves. Ledeen Mfg. Co. Illustrations, diagrams, etc. in bulletin.

104 **Clad Steel Equipment.** Illustrated guidebook for cleaning and maintaining clad steel equipment. From Lukens Steel Co. Solution formulas, cleaning procedures, other useful information given.

105 **Pressure Regulators.** Moore Products Co. line of pressure regulators listed in illustrated bulletin. Schematic drawings in color, graphs, capacities, applications, etc.

106 **Centrifugal Pumps.** Single-stage, double-suction centrifugal pump bulletin from Allis-Chalmers Mfg. Co. Carries tables of sizes, dimensions, head capacities. Applicable to paper, chemical, food, petroleum industries.

107 **Weighing and Proportioning.** Sintering Machinery Corp. line of conveying, weighing and feeding units for chemical food, paper, soap industries. Bulletin.

108 **Belt Conveyor Carriers.** Designed with spun end rollers and welded steel frame, belt conveyor carrier from Stephens-Adamson Mfg. Co. Features interchangeable parts, easy lubrication. Bulletin.

109 **Wires and Cables.** For use by chemical and petroleum industries, wire and cable from U. S. Rubber Co. Sections on insulation and jacket compounds, construction, technical data. Compounds include butyl, heat- and moisture-resistant insulations, neoprene and polyvinyl chloride jackets.

110 **Autoclaves.** Blaw-Knox Division of Blaw-Knox Co. catalog on autoclaves for pressure-temperature reactions. Specifications, agitation, instrumentation discussed. Tables, sectional drawings, features.

111 **Chrome Stainless Steel.** News letter from Carpenter Steel Co. contains facts and figures on special stainless steel for wide application.

112 **Flexible Valves.** Pinch-type nonplugging flexible valves by Farris Flexible Valve Corp. Catalog gives flow characteristics, capacities, pressures, selection charts, maintenance instructions, etc.

114 **Regulators.** Illustrated step selection chart from Foster Engineering Co. for pressure regulation. Installation suggestions, tables on steam, gas, water capacities, schematic drawings, flow sheets simplify selection of proper regulator or governor.

115 **Bamag System.** Hydrogenation of oils and fatty acids by the Bamag system illustrated in color in leaflet from General Industrial Development Corp. Table on hydrogen consumption and illustrations.

116 **Mills.** Pebble and ball tube mills, plus other types from Hardinge Co., Inc. Bulletin discusses applications, construction, specifications. Illustrated.

117 **Celite.** The Celite Story published by Johns-Manville. Origin, production, application, etc. on diatomaceous earth.

118 **Hastelloy Alloy F.** A nickel, molybdenum, chromium, iron alloy developed by Haynes Stellite Co. Handles acid and akaline solutions; good hot working qualities. For use in chemical, metal, petroleum industries. Bulletin.

119 **Refinery Construction.** A pictorial report of the refinery built by Lummus Co. at Dunkirk, France.

120 **Rotary Pumps.** Folder from Lammert & Mann Co. on rotary vacuum pumps, compressors, pressure blowers. Specifications, types, duty, sizes, etc. listed. Illustrations.

121 **Pulverizer.** Pulverizing grindable materials to micron sizes subject of folder from Schutz-O'Neill Co. Capacity ratings, schematic drawings, other data.

122 **Dust Collectors.** Torit Mfg. Co. dust collection units. Catalog describes and illustrates each unit, gives details with engineering drawings, tables, etc.

123 **Precision Meters.** For automatic controls in delivery of liquids, Repeat-O-Matic meters from Automatic Liquid Meter Co. Folder shows diagrams, operating advantages, etc.

124 **Transmission Systems.** Pneumatic, magnetic, electric, electronic transmission systems for flow, pressure, viscosity, by Fischer & Porter Co. Illustrated catalog contains characteristics, schematic diagrams of various systems.

125 **Nylon Parts.** Custom-molded nylon plastic parts from General Electric Co. Tables show mechanical, thermal, electrical, other properties.

126 **Control Instruments.** ElectroniK control instruments for measuring and control of process variables. Brown Instruments Division, Minneapolis-Honeywell Regulator Co. Catalog gives specifications, control action descriptions, ratings for electric and pneumatic types.

127 **Control Panels.** Bulletin from Bailey Meter Co. on control panels and accessories. Illustrated, shows modern methods. Source book for planners of control stations.

128 **Storage Bins.** Industrial storage bins of vitrified tile by Kalamazoo Tank and Silo Co. Information in bulletin on construction, schematic drawing, etc.

129 **Manifolds.** For cylinders of compressed gas, manifolds by Matheson Co., Inc. Folder illustrates layouts, fittings. Also information on regulators.

130 **Dynamometer.** W. C. Dillon & Co., Inc. bulletin on dynamometers. Capacities 500 to 100,000 lb.

131 **Automatic Boilers.** Oil or gas-fired automatic boilers, sizes 10 to 500 hp. from Boiler Engineering & Supply Co., Inc.

132 **Floats.** Five types of copper, monel, brass, and steel floats in line of Chicago Float Works, Inc. Pamphlet shows applications, construction, shapes, tables of weight, illustrations.

133 **Bin Feeder.** Folder on Com-Bin feeder from Pulva Corp. For continuous feeding of sticky, mastic materials, filter cake, detergents, sludges, etc. Discharges at 2,000 lb./hr. with ¾-hp. motor.

134 **Condenser Tube Inserts.** Thomas G. Wilson, Inc. inserts for condenser or heat exchanger tubes. Prevents plugging by strainer action. Easily installed. Services up to 250° F; aluminum-brass.

135 **Temperature Control.** For controlling on-off temperature, proportioning 0 to 100% modulation through 2% scale length, temperatures in pyrometric range to 3600° F., Capacitrol from Wheelco Instruments Division, Barber-Coleman Co. Leaflet shows schematic diagram, lists specifications, other data.

136 **Bin-Level Indicators.** Improved Bin-Dictators permit easy access to operating mechanism, etc., better switch installation, greater flexibility in wiring. For use on bins storing bulk materials. Bin-Dicator Co.

137 138 **Alco Products Review.** (137) For petroleum refinery and petrochemical engineers, American Locomotive Co.'s spring edition. Outlines differences between A.S.M.E. and A.P.I.-A.S.M.E. codes for bolted flange connections. Provides design engineer with simple rules, charts and tables, and other data. (138) Additional bulletin on heat exchangers, evaporators, heaters, prefabricated and welded steel pipe. Types and sizes, sectional drawings, etc.

139 **Plastic Pipe.** U. S. Rubber Co. details on Uscolite plastic pipe and fittings. Nontoxic for foods, beverages, chemical solutions. Fittings with molded standard threads.

140 **High Pressure Equipment.** Catalog on wall tubing, valves, elbows, tees, etc. from High Pressure Equipment Co. Variety of types.

141 **Vacuum Furnaces.** F. J. Stokes Machine Co. folder on vacuum furnaces and application to high-vacuum processing of metals. Discusses types, advantages, capacities, other data.

142 **Vertical Pumps.** Vertical, submerged centrifugal pumps by Taber Pump Co. For corrosive liquids, solvents, caustics. Eliminates stuffing box. Schematic drawings, illustrations, data.

143 **Autoclaves.** Autoclave Engineers Inc. catalog on high pressure autoclaves, valves, and fittings. Charts, sectional drawings, available types and sizes, discussion of performance and use.

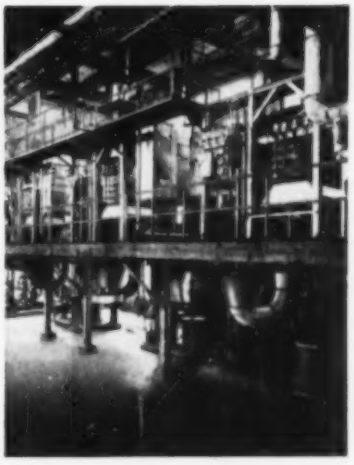
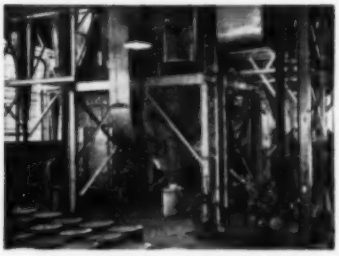
144 **Meters and Controls.** For engineers in power and process plants, catalog from Bailey Meter Co. on meters, controls and engineering services. Diagrammatic power-press applications of meters and controls. Pertinent data.

145 **Mixers and Blenders.** International Engineering, Inc. illustrated leaflet on size and specifications of conical blenders, principles of operation, etc. For the dyestuff, pigment, drug, food, chemical industries.

146 **Titanium and Alloys.** Properties of titanium and alloys in technical booklet from Mallory-Sharon Titanium Corp. Production, properties, test procedures, qualities of five available metals.

147 **Filters.** For food, drug, chemical industries, redesigned Titeflex, Inc. filters. Control valves relocated. Cleaning simplified by backwashing flow through membranes. Models from 300 to 10,000 gal./hr. on water.

148 **Slurry Pumps.** Oliver United Filters, Inc. diaphragm slurry pumps. No mechanical linkage to diaphragm, no stuffing boxes. Controlled number of variable strokes. Details, charts, other data in folder.

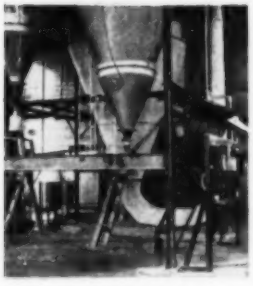
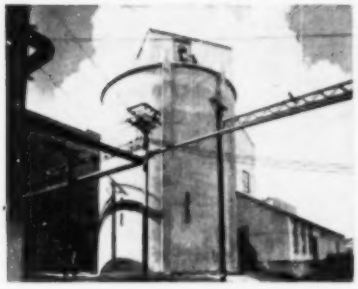
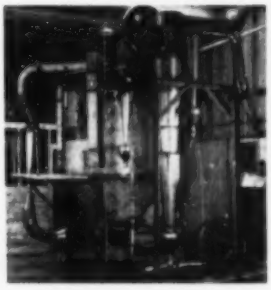
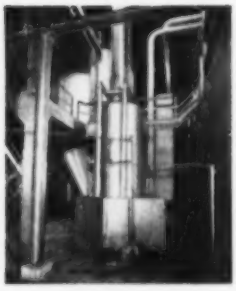
21 Recent Bowen Spray Dryer Installations that help prove the fact that

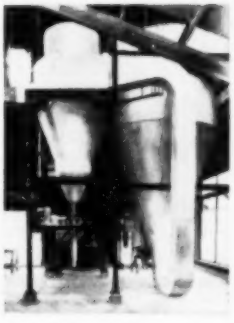
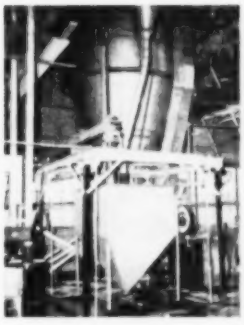
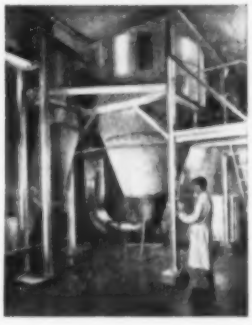
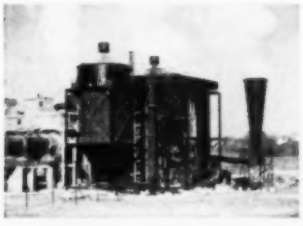
BOWEN SPRAY DRYERS

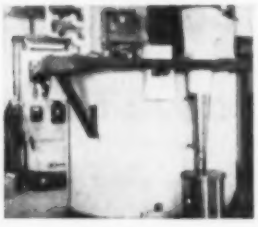
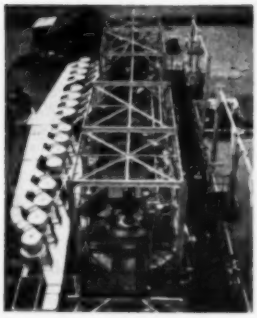
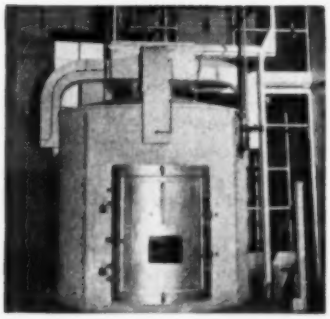
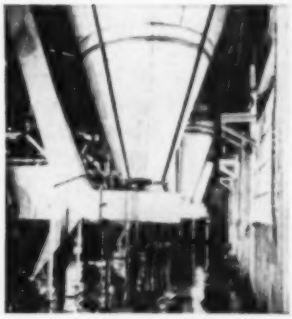
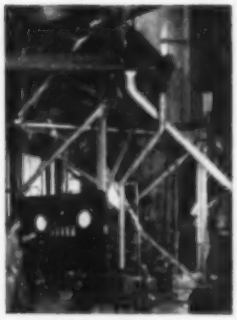
Always Offer You More!

Write for illustrated booklet—
The Bowen Spray Dryer Laboratory

BOWEN ENGINEERING, INC.
NORTH BRANCH 13, N. J.

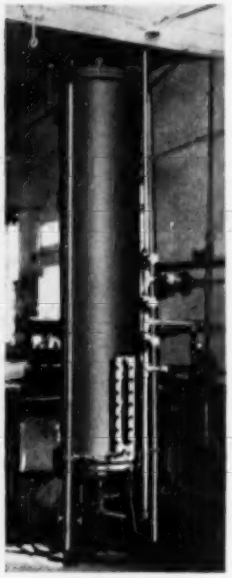





Barnstead

Mixed Bed Demineralizers

10 TO 2500 GALLONS OR MORE PER HOUR



In 3 years of operation, this 500 gallon per hour Barnstead Demineralizer has produced over four million gallons of high purity demineralized water with a minimum of maintenance or attention.

The sturdy construction and simplified design, plus the new and improved regeneration system make the Barnstead Mixed Bed Demineralizers outstanding in performance.

Easy to operate — easy to regenerate — they produce ion-free water at very low cost, and with a Barnstead Mixed you get more gallons between regenerations.

Each unit is complete with regenerant tanks, flow meter, pressure gage, purity indicator, and simplified regeneration. Steel columns are lined with heavy sheet rubber.

WRITE TODAY FOR NEW

BULLETIN #126

ON

MIXED BED DEMINERALIZERS

Ask for Barnstead Pure Water Recommendations — Without Charge

Our engineers will gladly submit recommendations, specifications, operating-cost figures, and performance data. Since Barnstead builds Mixed-Bed Units, Two- and Four-Bed Demineralizers, and a complete line of Distilled Water Equipment, you are assured of unbiased advice.

82 Lanesville Terrace

75 Years of Progress in Pure Water 1878 1953

Forest Hills, Boston 31, Mass.

Barnstead STILL & STERILIZER CO.

CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 7, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Active Members will receive careful consideration if received before August 15, 1953, at the Office of the Secretary, A.I.Ch.E., 120 East 41st, New York 17.

Applicants for Active Membership

Atwood, C. H., *Charleston, W. Va.*
Bradley, R. T., *So. Charleston, W. Va.*
Chilton, Cecil H., *Oceanside, N. Y.*
Clark, William H., *Jeffersonville, Ind.*
Cole, Charles S., Jr., *Bryn Athyn, Pa.*
Conly, Robert S., *Baytown, Tex.*
Creager, John R., *Akron, Ohio*
Deatz, Robert E., *Louisville, Ky.*
Dobbin, R. E., *Pampa, Tex.*
Fernstrom, George A., *Seaford, Del.*
Goett, Edward J., *Plandome, N. Y.*
Graves, J. W., Jr., *Monsanto, Ill.*
Griffin, Robert B., *Millington, N. J.*
Hall, I. D., *Baytown, Tex.*
Hanson, George H., *Idaho Falls, Idaho*
Hashmall, Frank, *Flushing, N. Y.*
Hehner, Harry O., *E. St. Louis, Ill.*
Hendel, Frank J., *Newark, N. J.*
Hughes, Richard S., *So. Charleston, W. Va.*
Jackson, H. K., *Oak Ridge, Tenn.*
Kamack, Harry J., *Wilmington, Del.*
Koslov, Joseph, *Great Neck, N. Y.*
Lawless, Sydney, *Fairfield, Conn.*
Lee, L. Vandegrift, *Riverside, Conn.*
Mertens, Frederic T., *Rutherford, N. J.*
Mickley, Harold S., *Belmont, Mass.*
Nack, Edward J., *Louisville, Ky.*
Perrine, Clifford Verl., *Alhambra, Calif.*
Pierson, R. E., *Tulsa, Okla.*
Pope, Frederick G., *Langeloth, Pa.*
Renard, Jules, *Lubbock, Tex.*
Riffelmacher, John H., *Springfield, Mass.*
Schatz, Robert J., *Springfield, Mass.*
Schurig, W. Fred, *Huntington, N. Y.*
Schweder, H. P., *Los Angeles, Calif.*
Sellers, F. Burton, *New York, N. Y.*
Shepherd, Richard M., *Wallingford, Pa.*
Spector, Norman A., *New York, N. Y.*
Spooner, Franklin M., *Scotch Plains, N. J.*
Stewart, Robert F., *Los Angeles, Calif.*
Sullivan, William T., *Zion, Ill.*
Switzer, Robert L., *Long Beach, Calif.*
Teague, Abner F., *Alexandria, Va.*
Thompson, Robert G., *Pittsburgh, Pa.*
Twining, Joseph R., *Springfield, Mass.*
Willis, Allen E., *Wilmington, Del.*
Winn, Francis W., *Woodbury, N. J.*

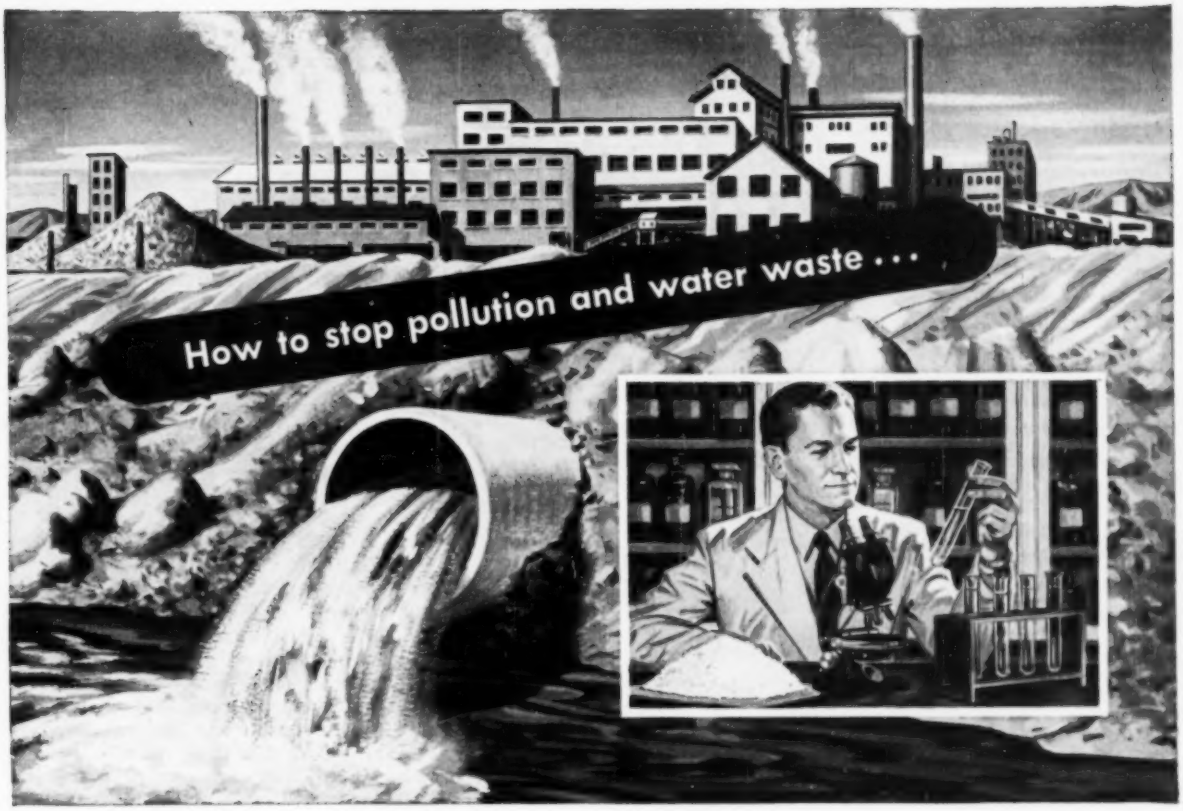
Applicants for Associate Membership

McKenna, Arthur J., *Park Forest, Ill.*

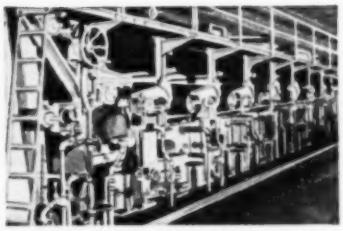
Applicants for Junior Membership

Aidun, Ardeshir R., *Syracuse, N. Y.*
Ambrose, Everett James, Jr., *Springfield, Mass.*
Bellinger, Duane W., *Pampa, Tex.*
Berresse, William G., *White Plains, N. Y.*
Blouch, C. H., *Philadelphia, Pa.*
Browning, Lewis M., Jr., *Wenonah, N. J.*
Byrd, Charles R., *Lake Charles, La.*
Cashin, Kenneth D., *Amherst, Mass.*
Clay, Edward B., Jr., *Philadelphia, Pa.*
Cortes, Ricardo, *New Martinsville, W. Va.*
Daumas, Felix A., *Asuncion, Paraguay*
Earle, Albert P., *Minneapolis, Minn.*
Edwards, Ray J., *So. Charleston, W. Va.*
Evers, Henry H., *So. Charleston, W. Va.*
Flack, Herbert Paul, *Baltimore, Md.*
Gisser, Philip, *So. Charleston, W. Va.*
Gretton, Avery T., *Spencerport, N. Y.*
Gross, Joseph F., *Clifton, N. J.*
Hall, Richard H., *Newark, Del.*

(Continued on page 52)



CELITE FILTRATION removes harmful impurities and purifies water for re-use



In paper plants "White" water used in paper formation is purified for re-use by Celite Filtration. The Celite method can also provide clean pure process water in many other industrial uses—for boiler make-up, heat exchangers, circulating water for towers, etc.

In oil wells—output is boosted by re-pressurizing wells with water to force out accumulated oil. Celite Filtration purifies water to the extreme degree required—removes the minute suspended impurities which would otherwise clog the microscopic pores of sandstone.

CELITE* FILTRATION can reduce your process water costs materially—and it can greatly aid your community's water conservation and anti-pollution programs.

If your plant now discharges industrial water as waste, Celite Filtration enables you to purify this water for *re-use*—at relatively low cost. Celite removes all types of suspended solids. When required, it even filters out fine matter such as amoebae and algae, many of which cannot be removed by other methods. Thus by recycling process water you can save on water costs . . . and save your community's water.

At such times as you still find it necessary to discharge process water, Celite Filtration is an important anti-polution measure. It helps make water safe and harmless . . . thereby protecting your community's recreational areas, fish and wildlife.

Food processors, beverage manufacturers, swimming pool operators and many industrial users of process water depend on Celite Filtration.

It will pay you to investigate the unique advantages of Celite for your particular application. Celite itself is carefully processed from the purest deposits of diatomaceous earth. It comes in nine standard grades, and you are always assured of utmost uniformity of product. To have a Celite engineer study your problem and offer recommendations, simply write Johns-Manville, Box 60, New York 16, New York. In Canada, 199 Bay Street, Toronto 1, Ontario. *T.M. Reg. U.S. Pat. Off.

JOHNS MANVILLE JM PRODUCTS

Johns-Manville CELITE FILTER AIDS

CANDIDATES

(Continued from page 50)

Hartman, Donald M., *Stuart, Fla.*
Harvey, Phillip D., *Richmond, Calif.*
Hughes, Charles F., Jr., *Freeport, Tex.*
Janka, Raymond C., *St. Louis, Mo.*
Kearney, Francis E., *Chicopee Falls, Mass.*
Kraut, Seymour, *Brooklyn, N. Y.*
Kroll, Charles L., *New Brunswick, N. J.*
Kyllonen, David M., *Tarentum, Pa.*
Laehder, Albert D., *Red Bank, N. J.*
Latorre, Hernando, *New York, N. Y.*
Lovell, Lyle M., *Texas City, Tex.*
MacLean, David C., *New York, N. Y.*
Maletsky, Albert H., *Hawthorne, N. J.*
Malmsten, Albert C., *Wyandotte, Mich.*
Massa, Harry E., *Euclid, Ohio*
McDonough, Robert, *Columbus, Ohio*
McElroy, I. R., *Louisville, Ky.*
McGinnity, William E., Jr., *Calumet City, Ill.*
McManus, John J., Jr., *Baton Rouge, La.*
Mead, Donald B., *Akron, Ohio*
Melino, Ralph C., *Garfield Heights, Ohio*
Modrunic, Richard D., *Pittsburgh, Pa.*
Naylor, Robert W., *Lebanon, N. J.*
Nichter, John R., *Schenectady, N. Y.*
Perge, Alex F., *Wilmington, Del.*
Pollack, Morton, *Brooklyn, N. Y.*
Powers, John E., *Albany, Calif.*
Protulis, James C., *Springfield, Mass.*
Ramey, Henry J., Jr., *Dallas, Tex.*
Reeve, Thomas B., *Cleveland, Ohio*
Richardson, R. J., *Cambridge, Mass.*
Sandlund, Herbert A., *Springfield, Mass.*
Santini, William A., Jr., *New York, N. Y.*
Scherr, Rodney W., *Charleston, W. Va.*
Schmid, Charles J., *St. Louis, Mo.*
Schreiber, David, *Niagara Falls, N. Y.*
Scogin, Robert J., *Kingsport, Tenn.*
Seward, Gordon B., *Akron, Ohio*
Shawd, Edgar A., *Houston, Tex.*
Somers, Allen E., *Pittsburgh, Pa.*
Sotir, Socrates P., *Summit, N. J.*
Spencer, H. G., *Richland, Wash.*
Steinhagen, James D., *Richmond, Va.*
Stoll, Walter O., Jr., *Evanston, Ill.*
Streaker, Harold A., *Los Angeles, Calif.*
Thaler, James D., *San Francisco, Calif.*
Watson, P. B., Jr., *Louisville, Ky.*
Wiltshire, Edward G., *Rossland, B. C.*
Witbeck, Paul C., *Pittsfield, Mass.*
Withers, Harry J., *Wyandotte, Mich.*
Zeh, J. Howard, *Pittsburgh, Pa.*

SAFETY HANDBOOK ON RADIOISOTOPES READY

A report entitled "Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water" has been published by the Subcommittee on Permissible Internal Dose, of the National Committee on Radiation Protection. It considers about seventy radioisoptopes that are of present-day interest. Other radioisotopes will be treated in subsequent reports as data become available, the committee promises.

The physical and chemical forms of the radioisotopes, according to the report, help to determine the type of radiation hazard and to some extent the degree of rettention in the body and the magnitude of hazard. Other factors affecting the hazard, it stresses, are the quantities of radioactive material involved, facilities and equipment available for handling radioisotopes, training and experience of those working with radioactive material, and their respect for appropriate protection procedures.

The report is the National Bureau of Standards Handbook 52, which may be ordered for twenty cents from the Government Printing Office, Washington 25, D. C.

Low Cost Protection for

HEAT EXCHANGER TUBE ENDS

In the past 31 years Conseco has provided millions of Flowrites for tube inlets of heat exchangers operating in all industries and all applications. Tube inlets become eroded and worn long before the remainder of the tube, and by reinforcing the inlets it is possible to increase the effective tube life many times.

Flowrites—made of the same metal as the tubes—are available in any length, diameter or gauge. They are easy to install and remove by unskilled help. When Flowrites themselves become worn (*instead* of the tubes!), just pull them out and install new, longer Flowrites.

Get the facts from the 8-page Flowrite "proof" booklet, available upon request.

CONDENSER SERVICE & ENGINEERING CO.

80 RIVER ST., HOBOKEN, N. J.

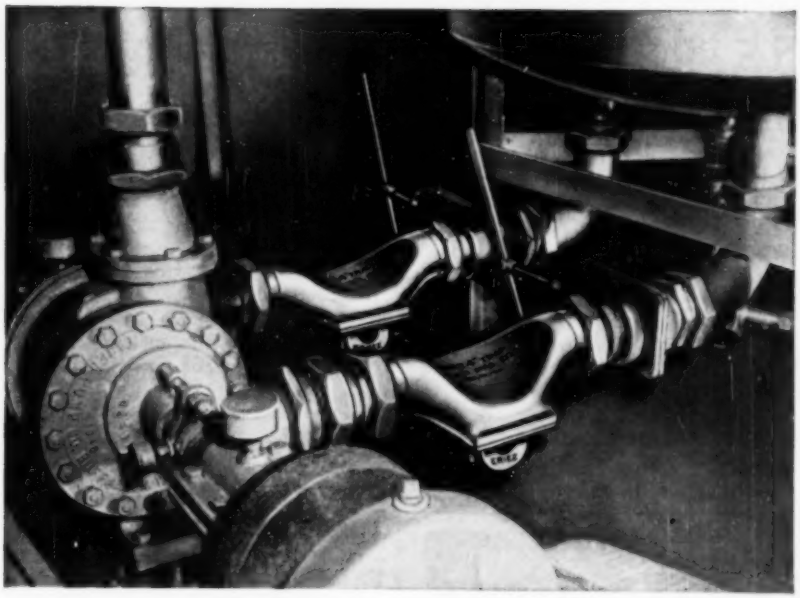
when you go courting lower costs

first check the SPRAY NOZZLES used in the system

More exact spray nozzle design...with nozzle capacity better adapted to the character of the liquid being sprayed can often materially improve spraying operations and lower your costs. That's why Spraying Systems Spray Nozzles are worth checking. Thousands of types and capacities to choose from. Designed and built by America's leading spray nozzle manufacturers. The most widely used nozzles in America today among equipment builders and engineering firms.

WRITE TODAY . . . let us send you General Catalog No. 22 and Pneumatic Atomizing Nozzle Catalog No. 23. Scores of Data Sheets also available covering specialized applications.

SPRAYING SYSTEMS CO.
3284 Randolph Street
BELLWOOD • ILLINOIS



ERIEZ MAGNETIC PIPELINE TRAPS, widely used in the process industries, provide the superior magnetic strength of a high nickel alloy . . . ALNICO . . . to assure positive trapping of tramp iron. Housings are non-magnetic chromium-nickel stainless steel castings . . . leak-proof, easy to install and simple to clean. Completely non-electric . . . first cost is last cost . . . since magnets hold strength during life of equipment.

1,045 PIECES OF TRAMP IRON REMOVED ahead of vane-type displacement pump in food production line during a 30-day period, by an ERIEZ Permanent (non-electric) Magnetic Pipeline Trap.

Prevent

→ *Machinery Damage*

→ *Product Contamination*

→ *Production Tie-Ups*

. . . Automatically, with Eriez Magnetic Traps

Look at this pile of tramp iron . . .

Trapped ahead of a pump in a large food plant during a 30-day processing period . . . it exemplifies how "protection plus" is obtained automatically with pipeline traps produced by ERIEZ MANUFACTURING COMPANY, Erie, Pa.

To keep liquid flow lines free of ferrous materials ranging in size from minute particles to large pieces of tramp iron, ERIEZ pipeline traps utilize the strong magnetic properties of Alnico permanent magnets containing a high percentage of nickel.

Use of this aluminum-nickel-cobalt-iron alloy not only permits trap designs that eliminate need for electromagnets requiring current and accessory equipment, but its use also allows reduction of space and weight requirements to desirable limits.

The addition of nickel . . . an essential in Alnico . . . improves scores of other alloys utilized throughout industry. Consult us on use of nickel or nickel alloys in your products or equipment.

Send details of your metal problems for our suggestions.

At the present time, nickel is available for end uses in defense and defense supporting industries. The remainder of the supply is available for some civilian applications and governmental stockpiling.

INCO

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

SECRETARY'S REPORT

S. L. TYLER

The Executive Committee of the Institute met on June 15 at the offices of the Institute. All those applicants for membership whose names appeared in the May, 1953, issue of "C.E.P." were elected to the grades of membership indicated and, in addition, the two applicants on whom action had been withheld from the previous listing in the April issue were elected. There were also fifty-six Student members elected.

K. N. Kettenring was appointed, at the request of the chairman, to the Committee on the Future of the Institute. J. P. Cooke was appointed to replace H. E. Hanthorn, representative of the Columbia Valley Section on the Public Relations Committee.

Upon recommendation of the chairman, Student Chapters Committee, the following Student Chapter counselors were appointed:

R. Wayne Houston to succeed J. M. Church at Columbia University; L. Wender to succeed J. M. Peterson at Cooper Union; and H. E. Schweyer at the University of Florida to succeed W. H. Beisler.

F. D. Atkinson was placed on the Suspense List because he entered the Armed Forces and W. H. Ailor and W. R. Kellogg were removed from this List because of their return to civilian status.

Secretary reported the receipt of $478.05, representing surplus from the operations of the Institute Meeting at Biloxi, and this amount was credited to the Institute Meetings Account.

W. F. Bixby was appointed Institute representative on the American Standards Association Committee A 13—Scheme for the Identification of Piping Systems.

The Treasurer's report for the month of May was received and approved.

The Council met at The Chemists' Club on the afternoon of June 15. This meeting really became a "farewell" to C. R. DeLong, who was resigning as Treasurer, and a "welcome" to G. G. Brown, who had accepted the appointment as treasurer. A wrist watch was presented to C. R. DeLong in recognition and appreciation of his seventeen years of service to the Institute.

The Minutes of previous meetings of Council and the Executive Committee were received and approved.

A recommendation from the Program Committee that approval be given to the holding of a meeting of the Institute at Lake Placid, N. Y., with the Lake Placid Club as headquarters, Sept. 25-28, 1955, and that the annual meeting in 1955 be held in Detroit, Mich., Nov. 27-30 with the Hotel Statler as headquarters, was accepted.

The Publications Committee had requested that further funds be made available to complete the analyses and correlations of information obtained on the questionnaire. They pointed out that the number of questionnaires returned by the membership was more than double what would normally be anticipated and Council therefore approved a $1,500 appropriation to continue the analysis of the Questionnaire.

P. H. Groggins, as liaison member of Council representing the Public Relations Committee, reported at length on the activities of this committee in recent months. Several matters which had been under discussion by the Committee were presented to Council but no definite actions were taken. These subjects were important and therefore were to be made an item of prime importance at the September meeting of Council.

The Council approved the formation of a Nuclear Engineering Section of the Institute in recognition of the importance of this field of engineering to the chemical engineer. A new bylaw

(*Continued on page 56*)

RESIMENT

FURANE RESIN CEMENT FOR CORROSION RESISTANCE

RESISTS { ACIDS
ALKALIES
SOLVENTS

Resiment is a furane resin cement shipped in the form of a powder and liquid for mixing at time of use. It is characterized by very low porosity, high compressive and tensile strengths and excellent resistance to acids, alkalies and solvents. It is likewise inert to fresh or salt water or steam. Resiment is recommended for use as a mortar for acid-proof masonry in tank linings, floors, sewers, towers and similar installations and may be used safely at temperatures up to 375°F. Resiment sets quickly by internal chemical reaction. Resiment takes an initial set within 20 to 30 minutes at room temperature and curing time varies with temperature conditions. Resiment can also be used for the molding of process equipment such as tanks, ducts, fittings, and pipe.

For further information please contact

DELRAC CORPORATION

P. O. BOX 118 TELEPHONE 168

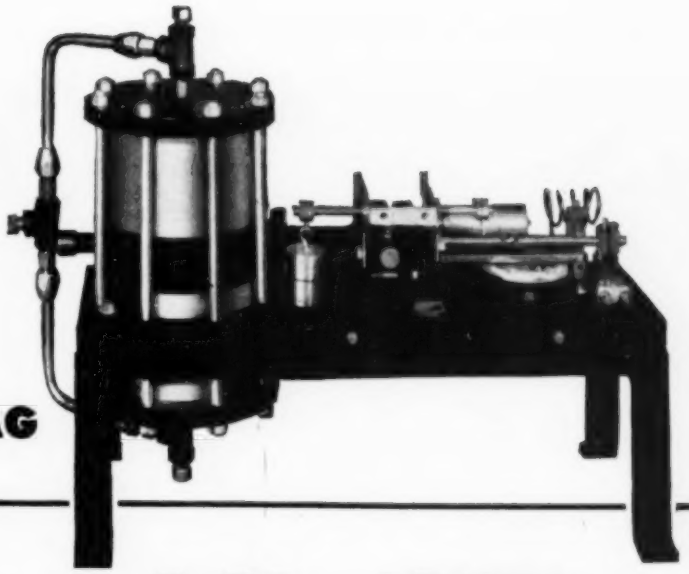
139 Mill Street

WATERTOWN, NEW YORK

MEASURES DENSITY

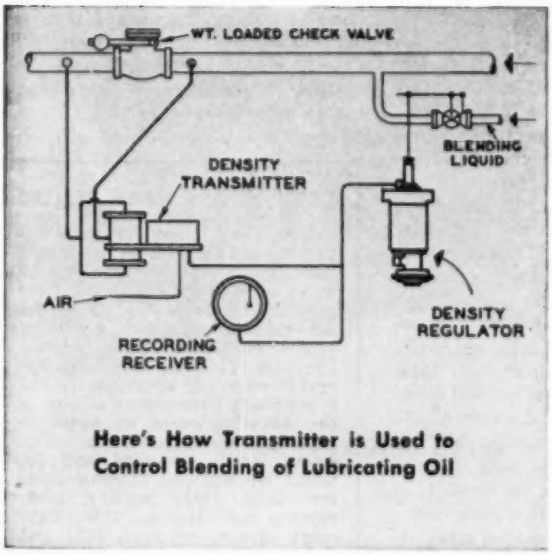
of flowing liquids

with **MINIMUM LAG**



Republic DENSITY TRANSMITTER

- **Makes a Continuous Density Measurement at Line Pressures to 300 psig.**
- **Transmits Air Loading Pressure Proportional to Flow Density to Remote Reading Instruments and Control Devices.**



Here's How Transmitter is Used to Control Blending of Lubricating Oil

Continuous measurement of flow assures prompt detection of density changes . . . permits corrections while liquid is still in flow line. There's no intermittent sampling to cause errors or lags.

Transmitter is all metal; contains no glass tubing to limit its application to very low pressures. For corrosion resistance, transmitter can be furnished in a wide variety of metals including nickel.

Narrow range spreads as small as 0.05 equivalent specific gravity for extreme accuracy of measurement are available. Accuracy is guaranteed to 1/2 of 1% of range spread for all ranges.

Get all the facts about this instrument. It's fully described in Data Book 1004. Write for your copy now.

REPUBLIC FLOW METERS CO.

2240 Diversey Parkway, Chicago 47, Illinois

CABOT RESEARCH EXPANDED BY NEW LABORATORY

The new research laboratories of Godfrey L. Cabot, Inc., Boston, Mass., were officially opened this spring. The building houses nine laboratories, including a two-story pilot plant with an area of 1,500 sq.ft. of floor space. Products of the Cabot laboratories include carbon black, plasticizers, pine-tar products, wollastonite, clay, and oil-well pumping equipment.

SOLAR ENERGY MEETING TO BE HELD AT WISCONSIN

The National Science Foundation recently announced a grant of $6,000 to the University of Wisconsin, Madison, for joint support of a conference on solar energy and its utilization, to be held September 12 to 14, 1953. Convened to stimulate research in the field, the conference will discuss such subjects as conversion of solar energy into electricity and heat; storage of solar energy in various ways, including chemical reactions; and use of fluid-solid phase changes and crystal alterations as mechanisms for energy storing.

About thirty engineers and physical scientists from the United States and abroad are expected to attend the conference. The planning committee consists of Farrington Daniels, chairman, professor of physical chemistry, U. of Wisconsin; Werner A. Baum, professor of meteorology, Florida State University; F. G. Brickwedde, National Bureau of Standards; Hoyt C. Hottel, professor of engineering, M.I.T.; Everett D. Howe, professor of mechanical engineering, U. of California, Berkeley; and Ralph A .Morgen, program director for engineering at the National Science Foundation.

G. G. BROWN TO GIVE 1953 INSTITUTE LECTURE

George Granger Brown, dean of the College of Engineering, University of Michigan, has been designated the Institute Lecturer for 1953. He will address the annual meeting in St. Louis in December on some aspects of thermodynamics as applied to chemical engineering.

Dr. Brown, who was President of A.I.Ch.E. in 1944, was the winner of the Walker Award in 1939. Last month he was appointed Treasurer of the Institute to fill out the term of C. R. DeLong, who requested to be released. Besides his Institute and university work, Dr. Brown is a director of Nash-Kelvinator Corp. and was in 1950 director of the engineering division of the U. S. Atomic Energy Commission.

The Institute Lectures were initiated five years ago to provide the members at each annual meeting with a comprehensive coverage of some essential aspect of chemical engineering. The lecture, usually in expanded form, is published in the Monograph Series of "C.E.P."

Previous Institute Lecturers have been W. R. Marshall, Jr., Thomas B. Drew, Olaf A. Hougen, and W. H. McAdams.

SECRETARY'S REPORT

(Continued from page 54)

will be prepared for the authorization of this section and outlining the conditions under which it will operate.

The Chemical Engineering Education and Accrediting Committee made recommendations to the Council regarding accreditation of chemical engineering curricula. There were sixteen chemical engineering curricula in which accrediting shall be continued from two to five years. Following this action of Council, the E.C.P.D. will be notified of the actions taken. The actual reporting of completed actions will not be available until October when the E.C.P.D. has completed its work.

The Secretary pointed out that the question of housing for the headquarters of the Institute was a pressing problem and that there were several possibilities as to the method of solving it. He, therefore, requested the appointment of a committee of Council to investigate the entire question of housing. A Committee consisting of E. P. Stevenson, Chairman, G. G. Brown, R. P. Kite, F. J. Van Antwerpen and S. L. Tyler was appointed.

The Secretary presented proposed modifications to the Constitution of E.J.C. which were recommended to the constituent societies by the E.J.C. after careful study. These were approved.

Secretary presented a list of 202 members whose dues were in arrears for a period of eighteen months. In accordance with the Constitution, such memberships would be terminated as of June 30, unless payment was made. The Council voted to act accordingly.

Other matters of policy were discussed but no action was taken.

SAVE THOSE BACK ISSUES

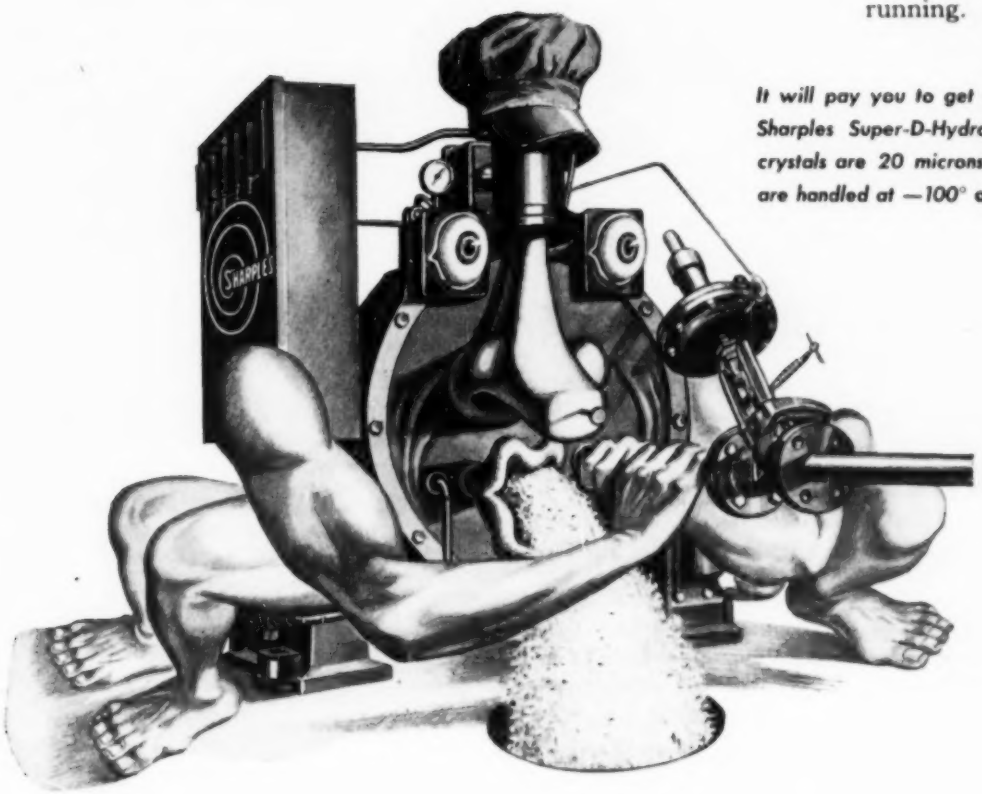
Every so often an unprecedented demand for a particular issue, or an unexpected influx of new subscribers and members puts the editor in the embarrassing position of running out of copies of Chemical Engineering Progress. This has happened several times in our short history and if members have copies of any of the following issues, we would be glad to purchase them. The issues which we need and for which we will pay 75 cents each, are: May, 1947; January, 1949; August and October, 1950; February, March, and April, 1951, and February, 1953.

All these issues were overprinted to a great extent, but because of features and other demands, single copy sales, etc., they were completely exhausted in a short time.

Built ruggedly for tough crystal dehydration service—that's the reason why performance records of over 200 Super-D-Hydrators show low operating costs and high purity dry crystals. Every detail has been engineered to withstand the most severe operating conditions. Oversize bearings, heavy duty basket, rugged knife and leveller, all combine to give dependable continuous service.

The Super-D-Hydrator is extremely flexible. Instrumentation control provides quick, easy adjustment for variations in slurry concentration, flow rate, and crystal size—independently, and while the machine is running.

BRUTE FOR CRYSTALS



It will pay you to get the facts about The Sharples Super-D-Hydrator — whether the crystals are 20 microns or 4 mesh in size, are handled at —100° or 400° F.

Write for Bulletin #1257

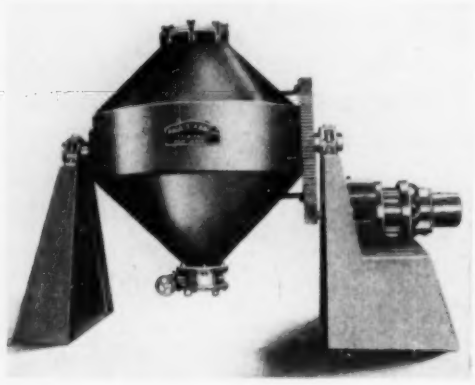
SHARPLES

THE SHARPLES CORPORATION • 2300 WESTMORELAND STREET • PHILADELPHIA 40, PENNA.

NEW YORK • PITTSBURGH • CLEVELAND • DETROIT • CHICAGO • NEW ORLEANS • SEATTLE • LOS ANGELES • SAN FRANCISCO • HOUSTON

Associated Companies and Representatives throughout the World

It's Unique! PAUL O. ABBÉ DOUBLE CONE BLENDER



Paul O. Abbé double cone blenders have certain unique advantages and features that are found in no other type of blender.

In these blenders any number of dry ingredients can be blended simultaneously.

- **No gadgets inside the cones are used that will obstruct the free flow and blending of the different particles.**
- **Striking the conical walls, materials are deflected toward the center and no two particles take parallel paths.**
- **Velocities of the various particles differ greatly but set up a general pattern that results quickly in complete homogeneity—the one purpose of a practical dry blender.**

Many features, such as easy to use loading and discharge valves, gear drive, and correct engineering design contribute to make Paul O. Abbé Twin Cone Blenders the fastest and most satisfactory machines for many types of blending.

Capacities 0.13 cu. ft. to 65 cu. ft. and more.

Write for our catalog V, further illustrating and describing these machines.

PAUL O. ABBÉ INC.

271 CENTER AVENUE **LITTLE FALLS, NEW JERSEY**

MARGINAL NOTES

(*Continued from page* 38)

Rex Flaharty's chapter "Tracer Experiments" is a particularly good one, in that it contains much information on techniques and pitfalls seldom found in texts.

While the objectives of the book are sound, and the need for the information therein is real, the book suffers from poor organization. A glossary of terms would be of help to the uninitiated in the field. An annexed bibliography would have made up for the lack of references in many of the chapters.

Nevertheless, this compilation of a wide range of useful information should be of considerable aid in the adaptation of radioisotopes to industrial problems.

Technology Emphasized

Phosphoric Acid, Phosphates, and Phosphatic Fertilizers, A. C. S. Monograph No. 34, 2nd Edition. William H. Waggaman. Reinhold Publishing Corp., New York (1952), 683 pp., $15.00.

Reviewed by John R. Van Wazer, Assistant Director of Research, Phosphate Div., Monsanto Chemical Co., Dayton, Ohio.

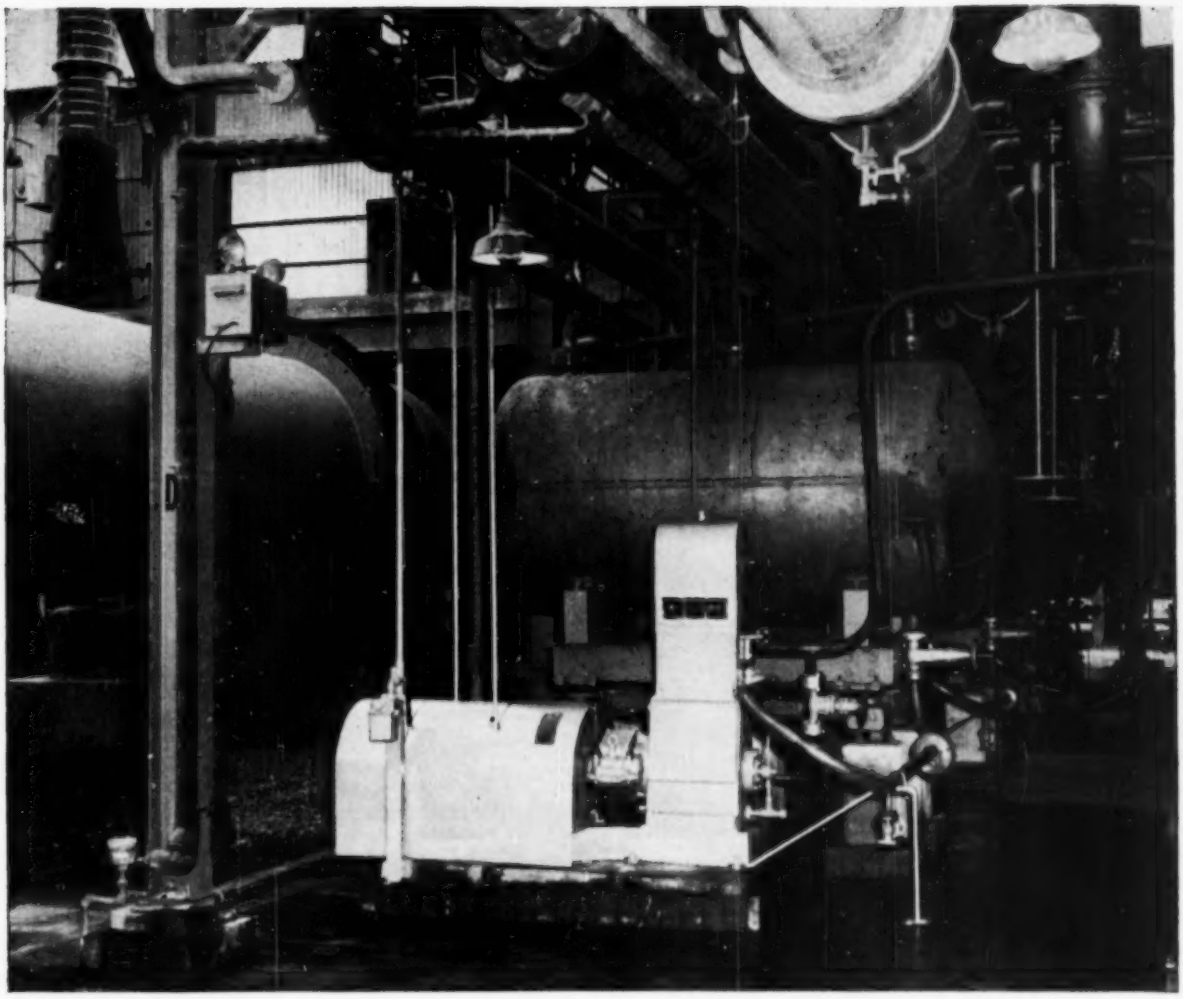
This discussion of the technology of phosphorus and the phosphates, including orthophosphoric acid, represents considerable revision and expansion over the first edition which appeared in 1927. The emphasis in the entire presentation is on technology, and little chemistry is presented. Unfortunately, part of the chemical discussion that is given is obsolete, and in some cases incorrect. For example, the formulas given in the first chapter for phosphorus acid, hypophosphoric acid, metaphosphoric acid, and the hypothetical metaphosphorus acid are definitely incorrect.

Seven chapters are devoted to the mining and practical geology of phosphatic ores.

The manufacture of phosphoric acids by the wet process is thoroughly discussed. The discussion of the manufacture of elemental phosphorus and of converting the element to phosphoric acid is based almost completely on the numerous publications in this field from the T.V.A.

Ten chapters are devoted wholly or in great part to the manufacture of phosphate fertilizers. All of the standard methods of fertilizer manufacture are discussed thoroughly. Detailed cost estimates give an over-all picture of the economics involved in the various manufacturing operations.

(*Continued on page* 60)



Another Chemical Pumping Job—handled by ALDRICH

This scene is the plant of a leading manufacturer of explosives, where the Aldrich Triplex Pump pictured in the foreground pumps nitric acid at the rate of 185 lbs. per minute against 400 psi maximum pressure.

It's one of many jobs Aldrich Pumps are called upon to do in the chemical industries. These versatile pumps are ideal wherever applications involve corrosion, abrasive materials, high viscosity or high pressure. In addition to nitric acid, among the many liquids handled by Aldrich Pumps are caustic solutions, fatty acids, acetic acid, aqua ammonia, anhydrous ammonia, as well as liquids encountered in the petroleum refining, petroleum chemical and other industries.

Several types of Aldrich Pumps are available to meet your specific needs. For automatically controlled delivery Aldrich-Groff "POWR-SAVR" Pumps can handle any free-flowing liquid at discharge pressures from 300 to 15,000 psi and are available in six sizes—from 2" to 6" stroke and from 5 to 125 bhp. (For information, write for Data Sheet 65.) For medium to high pressure service you may need one of the many Aldrich Constant Stroke Pumps—the Direct Flow Triplex or Multiplex Pump (Data Sheets 64, 64A, 64B).

Take advantage of our broad experience in building pumps for the chemical industry and let us make specific recommendations to meet *your* chemical needs. No matter what your problem, we welcome your inquiries or requests for literature.

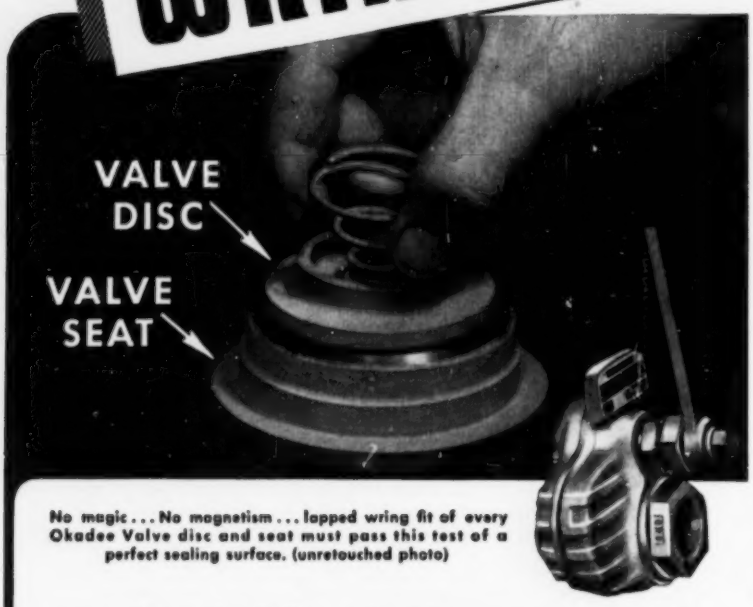
The Aldrich Pump Company

20 GORDON STREET • ALLENTOWN, PENNSYLVANIA

Representatives in Principal Cities

ALDRICH

Okadee
"THE PERFECT SEAL"
WRING FIT



No magic... No magnetism... lapped wring fit of every Okadee Valve disc and seat must pass this test of a perfect sealing surface. (unretouched photo)

...Here's What it Means to You in Terms of Valve Service

Flat mating surfaces within .000005", or less, of every set of Okadee valve discs and seats mean absolute shut-off of any material from ammonia gas to asphalt.

How long does this seal last in service? We honestly don't know. Tests under working conditions with propane were stopped after 269,000 operating cycles when no wear or seal failure could be detected. And Okadee valves do not have to be babied in service on corrosive or abrasive materials . . . Thousands of boilers have had Okadee blow-down valves in continuous, trouble-free service for fifteen years or more. If Okadee size-pressure-temperature ranges include your valve applications, Okadee installation will end your problems of valve performance once and for all.

Okadee valves are available in single-disc (one direction) and double-disc (two directions) types; screwed or flanged; ½" to 6" in standard A.S.A. dimensions; steel or semi-steel bodies (other materials to order); stainless steel or stellite seat facings; levers, rack-and-lever, worm-gear, hydraulic, pneumatic, automatic on-off control.

Write for Bulletin 332-F today!

OKd. Okadee COMPANY
333 South Michigan Avenue • Chicago 4, Illinois

MARGINAL NOTES

(*Continued from page* 58)

Leavening agents, flame-resisting products, and use of phosphates in the fields of water softening and detergency are given a reasonably thorough treatment. The technology (including manufacture) of the sequestering phosphates is reviewed, and a number of miscellaneous industrial applications of phosphoric acid and its derivatives are discussed.

Although the new edition gives an adequate presentation, this reviewer feels that the book will age rapidly. It offers little suggestion or premonition of advances yet to come.

Metallurgy for Engineers. John Wulff, Howard F. Taylor and Amos J. Shaler. John Wiley & Sons, New York (1952), 624 pp. $6.75.

Reviewed by E. G. Holmberg, Alloy Steel Products Co., Linden, N. J.

This text, supplemented with lectures and laboratory work, should provide an excellent course for students working for engineering degrees, which ultimately will lead them into a professional practice, where a general knowledge of metallurgy would be of value, if not a prerequisite. The practicing engineer would be edified by a reading of this book, as it presents the most recent developments for many metallurgical operations.

The text, however, has a weakness in that the authors have a tendency, in some chapters, to use theoretical information that should receive additional treatment, before, particularly the nonmetallurgical reader, can have a clear understanding of the phase being presented. A few minor errors in editing, not corrected in the final form, detract from clarity also.

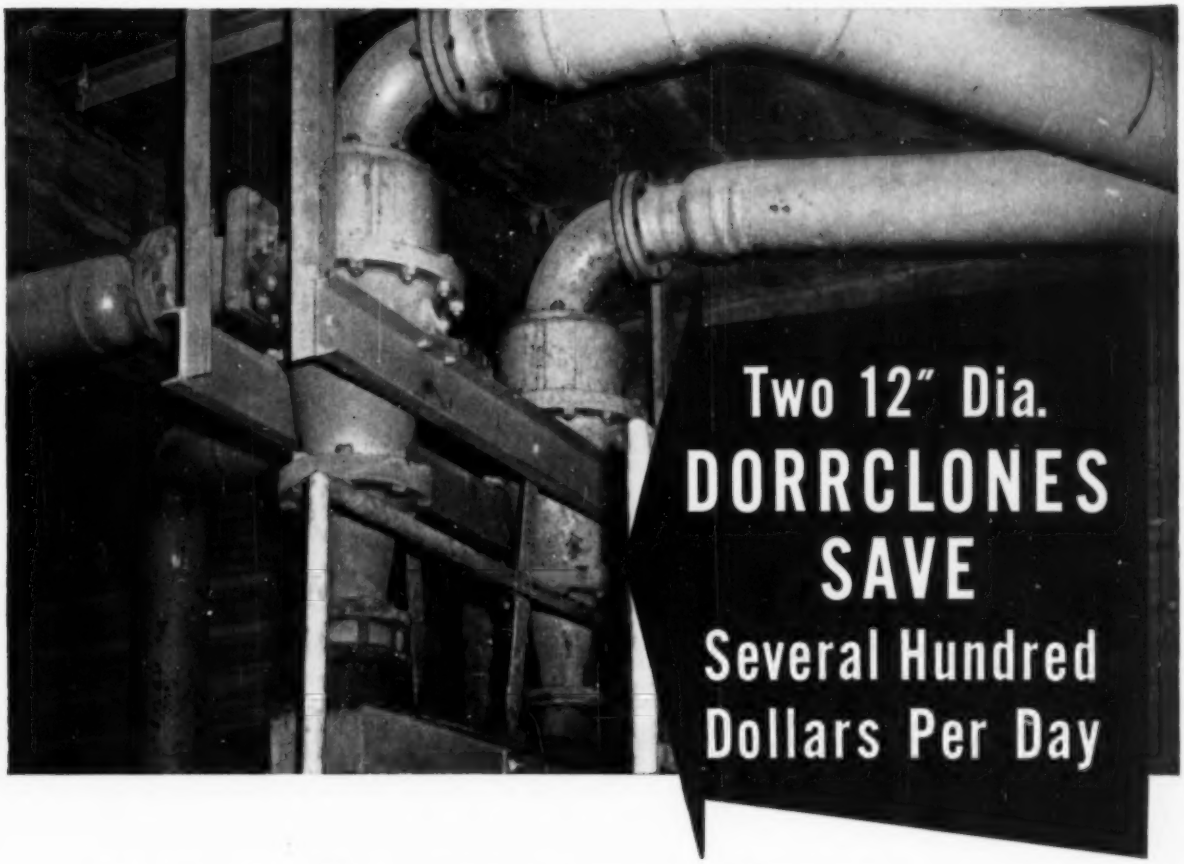
Still, even with these criticisms, the work has considerable merit and should prove a worthy adjunct to the library of the young engineer.

Books Received

Microwave Spectroscopy. Walter Gordy, William V. Smith, and Ralph F. Trambarulo. John Wiley & Sons, Inc., New York (1953). xii + 446 pp., $8.00.

The Characterization of Organic Compounds (Revised Edition). Samuel M. McElvain. The Macmillan Co., New York (1953). ix + 303 pp., $4.50.

Ion Exchangers in Analytical Chemistry. Olof Samuelson. John Wiley & Sons, Inc., New York (1953). xviii + 291 pp., $6.50.



On Raw Clay For Cement Manufacturer . . .

Problem: A Southeastern cement manufacturer needed clay of a certain composition for his mix. A local deposit was available but silica content ran too high for direct use. Alternatives were — bring in clay of a suitable grade from a distance . . . or find an economical way to up-grade the local material.

Solution: Two 12" dia. DorrClones were installed to classify the raw clay slip prepared from the local deposit. Required grades for the mix are produced at savings averaging several hundred dollars per day on raw clay costs.

Here's another case where the unique classification features of the DorrClone have paid off in a wet processing flowsheet. At this plant, three types of cement are produced . . . each requiring a specific grade of clay in the raw mix. Two 12" dia. DorrClones degrit high silicon content clay from a local deposit to supply all three grades. Equally important, silica is reduced to the desired amount in each grade simply by varying the feed pressure to the units. No additional dilution is necessary and the excess silica is removed as a low moisture underflow product.

If you have a desliming or degritting problem, there's a good chance that the DorrClone, with its high-capacity-for-size and ability to handle flocculent or heavy pulps, will be the solution. If you'd like further information on this flexible new unit, write for Bulletin No. 2500 to The Dorr Company, Stamford, Conn.

DorrClone is a trademark of The Dorr Company, Reg. U.S. Pat. Off.

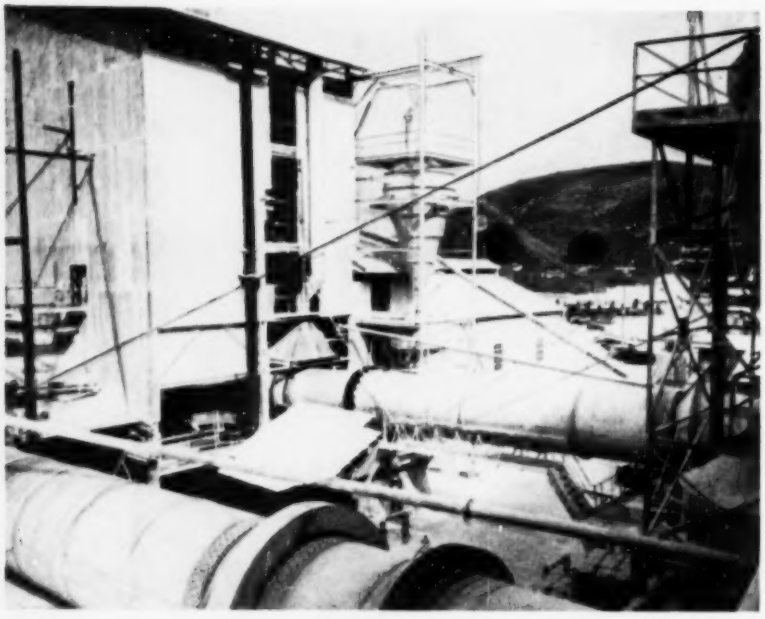
Better tools TODAY to meet tomorrow's demand

DORRCO

DORR

WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT

THE DORR COMPANY • ENGINEERS • STAMFORD, CONN.
Offices, Associated Companies or Representatives in principal cities of the world.



Two of the four rotary kilns in which diatomite is heat-processed at temperatures up to 2,000° F. at the Johns-Manville plant in Lompoc, Calif. Diatomite, which the company sells under the trade name Celite, is used as a filter aid, particularly in the processing of new "miracle" drugs.

LARGE NICKEL DEPOSIT FOUND IN CUBA

Discovery of a large deposit of nickel ore, which will create a major new source of this critically short metal, was announced recently by Freeport Sulphur Co. Located in the vicinity of Moa Bay, about 500 miles east of Havana, Cuba, the deposit contains, company officials said, at least 40,000,000 tons of nickel ore and, except for deposits in Canada, constitutes the most important proved source of nickel anywhere in the free world.

Freeport, according to John Hay Whitney, board chairman, will build a pilot plant to study the recovery of nickel and cobalt through its own sulfuric acid leaching process and a technique developed by Chemical Construction Co. The advantage of the latter technique, continued Mr. Whitney, is that it permits the recovery of cobalt from the ore and of nickel as a metal rather than as an oxide. The new deposits are reported to average about 1.35% nickel and 0.14% cobalt.

INDUSTRY URGED TO ENTER ATOMIC FIELD

The entrance of private industry "into the atomic energy field on a risk-taking, profit-making basis" was urged by Keith T. Glennan, president of Case Institute of Technology, Cleveland, in a recent address at the chartering of the Aluminum Research Laboratories as a branch of the Scientific Research Society of America.

He distinguished this "opportunity to serve the peacetime interests of the public and to make or lose money in the normal American way" from the present role of "hired hand" played by industries today operating on A.E.C. contracts. Dr. Glennan observed that changes would be necessary in the portions of the Atomic Energy Act of 1946 applying to production and ownership of fissionable materials and ownership of patents, rights which at present are held only by the A.E.C.

Dr. Glennan questioned the necessity for as much secrecy as now surrounds atomic energy production and gave four arguments for immediate action by industry: 1) eventual exhaustion of present fuel sources; 2) eventual satiety of fissionable materials for atomic weapons, which "do not deteriorate in the same sense that gunpowder does"; 3) necessity for reducing cost of reactors designed for power production to determine the economic practicability of atomic energy in this connection; 4) desirability of releasing control of peacetime uses of atomic energy from the government, as "history does not support the thesis that such developments are best handled by government. . . ."

There are certain tasks, however, which only the A.E.C. can handle satisfactorily, Dr. Glennan warned, particularly the production of U-235 and plutonium.

AIR POLLUTION IS COMBATED AT DU PONT

A new continuous soot-free process for producing synthesis gases has been announced by Du Pont Co., which is building a unit to utilize the process at its Belle, W. Va., works. Designed primarily to combat air pollution, the process is expected to be more efficient in the use of coal than are the coke ovens and gas generators which it will replace.

In the process, low-fusion-ash coal, instead of coking varieties, will be crushed to the fineness of talcum powder in pulverizing equipment using steam-driven jets. The powdered coal will be blown into a ceramic-lined furnace where at controlled temperatures the volatile matter and fixed carbon will be burned in the presence of steam and a deficiency of oxygen to give carbon monoxide and hydrogen. Carbon monoxide, except as used in the manufacture of ethylene glycol and other products, will be reacted with steam to give hydrogen and carbon dioxide. Hydrogen and nitrogen, the latter obtained in the production of oxygen from the air in separate equipment, will be used in making ammonia. The bulk of the ash will be drawn off as slag. The combustion furnace was designed in cooperation with and will be built by the Babcock and Wilcox Co.

CHEMICALS RATE HIGH IN INDUSTRIAL SAFETY

The safety programs of two chemical companies were recognized last month by the Manufacturing Chemists' Association, which awarded the Lammot du Pont Safety Plaques to the Naugatuck [Conn.] Chemical Division of U. S. Rubber Co. and the A. R. Maas Division of the Victor Chemical Works, Calif., for the greatest improvement in plant safety over a five-year period.

The Naugatuck Division, which won among chemical manufacturers with more than 2,000,000 man-hours' exposure, operated throughout 1952 without a lost-time accident. The Maas Division was the leader among firms with less than 2,000,000 man-hours. Runner-ups in the two divisions respectively were the Tar Products Division, Koppers Co., and Jefferson Chemical Co.

In announcing the winners, the association stated, "The chemical industry is one of the safest places to work. . . . For 1952 the average accident frequency rate for M.C.A. companies was 4.10 compared to 9.06 for all U. S. industry. For the first quarter of 1953, M.C.A. companies scored a further improvement with a rate of 3.47."

(*More News on page* 64)

DRYING PROBLEMS?

JUST WRAP 'EM UP AND SEND 'EM TO US . .

STRAIGHT ACROSS THE BOARD FROM ABRASIVES TO YARNS

HERE ARE A FEW OF THE PRODUCTS WE'VE TESTED IN OUR LABORATORY FOR MORE EFFICIENT DRYING

Abrasives
Apples
Asbestos
Bast Fibres
Beans
Bristles
Building Materials
Calcium Carbonate
Chemicals
Clay Fillers for paper
Cloth
Coatings
Coconut
Cotton
Dehydrated Foods
Explosives
Fertilizers
Flock
Flour
Fruits
Grain (cooling)
Hides
Hair
Kaolin
Latex
Macaroni
Metal Parts and Products
Nuts
Paints
Paper & Paper Products
Peanuts
Peat Moss
Pigments
Plastics raw stock
Printing Inks
Proteins
Pulp
Rice
Rubber—reclaimed, synthetic and natural
Salt
Sawdust
Sisal
Synthetic Fibres
Textiles—raw and dyed stock
Tobacco
Waste Sludges
Wool
Yarns

CAN YOU ANSWER THESE QUESTIONS ABOUT THE DRYING OF YOUR PRODUCT?

1. Is it dried uniformly, to exact degree desired — under complete control at every stage?
2. Are you getting maximum rate of production possible, yet maintaining automatically controlled, unvarying quality?
3. Is your drying process the most efficient possible — quality-wise, AND cost-wise? No steam or hot dry air waste? Using minimum floor area? And optimum bed depth? Would alternate airflow direction zones help, or radiant heat boosters, or varying temperature zones?
4. Is your product correctly pre-conditioned for most efficient drying? Have you ever compared drying curves to be certain that every important variable is controlled within pre-set limits — automatically?
5. Which type of dryer is best for your product — tunnel, pole, tray, truck, or special design?

SARGENT can give you the answers to these and many other questions. For better, less costly, more efficient operation of drying processes, write us.

May We Help You . . .

determine the one best commercially practical way to dry YOUR product easier, quicker, more economically? Just write us.

C. G. SARGENT'S SONS CORP.

Graniteville, SINCE 1852 Massachusetts

REPRESENTATIVES: F. E. WASSON, 519 Murdock Rd., Philadelphia 19, Pa.
A. L. MERRIFIELD, 215 Grove Ave., Cincinnati 15, Ohio
W. S. ANDERSON, Carolina Specialty Co., Charlotte, N. C.
HUGH WILLIAMS & CO., 47 Colborne St., Toronto 1, Canada

"MIGHTY MITE" SOLVES CHEMICAL PUMP PROBLEMS

The Eco All-Chem Pump is the All-Teflon and stainless steel pump that handles 70 percent of corrosive chemical requirements in Lab., pilot plant and small volume pumping in production service.

Simplify selection; standardize on fewer types, models, sizes; minimize maintenance problems.

READ THE SPECS . . . SPECIFY AND TRY

- *Type Pump:* Positive displacement with two opposed axially oscillating impellers equivalent to duplex piston operation.
- *Volume:* ½ to 10 g.p.m. maximum at 1750 RPM (water).
- *Pressures:* to 70 psi.
- *Suction Lift:* Highest over widest temperature and viscosity range.
- *Corrosion Resistance:* Lowest corrosion rate due to internal flow pattern. Handles all chemicals that stainless steel No. 316 will handle.
- *Pump Operating Characteristics:* Linear delivery. No air entrainment. Non-foaming. Unequalled for safety in handling hazardous liquids such as nitric acid and hydrogen peroxide. Self-priming on non-volatile liquids.
- *Drive:* Applicable to direct motor drive at 1750 RPM, as well as to all other standard driving methods.

All-Chem PUMPS

ECO

ENGINEERING COMPANY

12 New York Avenue • Newark 1 • New Jersey

NEWS

(*Continued from page 62*)

CHILTON URGES HEARINGS ON SELECTIVE RECALL

The necessity for public support of the new selective-recall bill for military service introduced into Congress as the Flanders-Johnson Bill (H.R. 3893 and S. 1551) was stressed recently by Thomas H. Chilton, chairman of the Engineering Manpower Commission of the Engineers Joint Council and former President of A.I.Ch.E.

Dr. Chilton cited the current shortage of certain categories of specialized personnel and stated that over 25% of engineers and scientists now in productive defense, development, and research could be placed in uniform almost overnight. Among the provisions of the bill, Dr. Chilton explained, are the establishment of a Manpower Board to be set up in the office of the President and a more selective system of recalling reservists.

The current Public Law 51 has created a compulsory reserve for military personnel upon completion of active service. Recalling these reservists to active duty rests solely in the hands of the Department of Defense, it was emphasized, with little or no provision made for occupational deferment.

The need, according to E.M.C., is for immediate hearings on the bill, and the Commission urges that every engineer write to his Congressman to press for action.

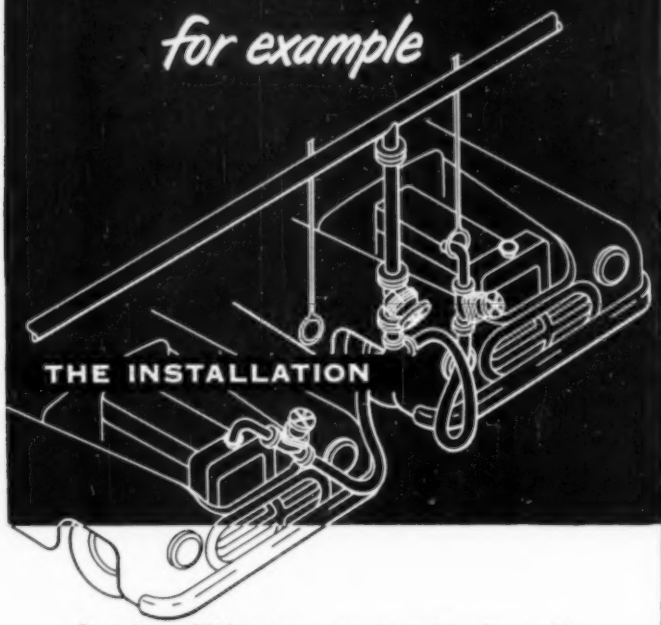
NEW VISCOSITY STANDARD ADOPTED

Beginning on July 1, 1953, the value of 0.01002 poise for the absolute viscosity of water at 20° C. will be adopted as the primary standard for the calibration of standard viscosity samples and viscometers by the National Bureau of Standards and the American Society for Testing Materials. The national Physical Laboratory in England and the Physikalisch - Technischen Bundensanstalt in Germany have also indicated acceptance of the standard on this date.

Hitherto the value of 0.01005 poise has been widely used as the primary reference standard. The new value will result in a reduction of 0.3% in the measured values of viscosity and will, according to the Bureau, make viscosities reported in absolute units correspondingly more accurate. Previously published data based upon the original standard may be adjusted by reducing the values by 0.3%.

(*More News on page 66*)

How Valve Life Changed from Days to Months ...on Crystalline Liquids, for example



In a large Midwestern auto assembly plant, with Crane Diaphragm valves in alcohol solution anti-freeze fill lines to automobile radiators.

VALVE SERVICE RATINGS

SUITABILITY:	Doing the job O.K.
FEATURES:	Packless; no leakage around stem
MAINTENANCE COST:	None
SERVICE LIFE:	Now 25 times longer than any valve used
OPERATING RESULTS:	Damage to production stopped
PRICE:	O.K. No premium
AVAILABILITY:	Regular Crane Catalog item. No. 1610

THE CASE HISTORY

None of the many conventional valves nor the plug cocks tried in this service lasted more than a week—about 2,000 operations.

The crystals present in anti-freeze would build up on seating surfaces and in the exposed valve stem threads. The valves leaked and were hard to operate. To the excessive maintenance needed was added the high cost of frequent damage to automobile finish by anti-freeze leakage.

Now Crane Packless Diaphragm valves control the trouble. Their sealed bonnet prevents contact of fluid and working parts; their seating design isn't hindered by crystal deposits. At last report, Crane valves have given over 50,000 trouble-free operations with no maintenance, and with indefinitely longer life assured.

THE VALVE

In Crane Diaphragm valves, the diaphragm serves only to seal the bonnet, not for seating. It isn't pinched or stressed when valve is closed. Independent disc gives control of fluid even should diaphragm fail. These valves are made in a wide variety of body, diaphragm, disc-insert, and body-lining materials to handle countless corrosive, abrasive, or ordinary services. See your Crane Catalog or local Crane Representative.

THE BETTER QUALITY...BIGGER VALUE LINE...IN BRASS, STEEL, IRON

CRANE VALVES

CRANE CO., *General Offices:* 836 S. Michigan Ave., Chicago 5, Illinois

Branches and Wholesalers Serving All Industrial Areas

VALVES · FITTINGS · PIPE · PLUMBING · HEATING

IMPERVITE

Impervious Graphite Pumps

Speed Chemical Processing Because:

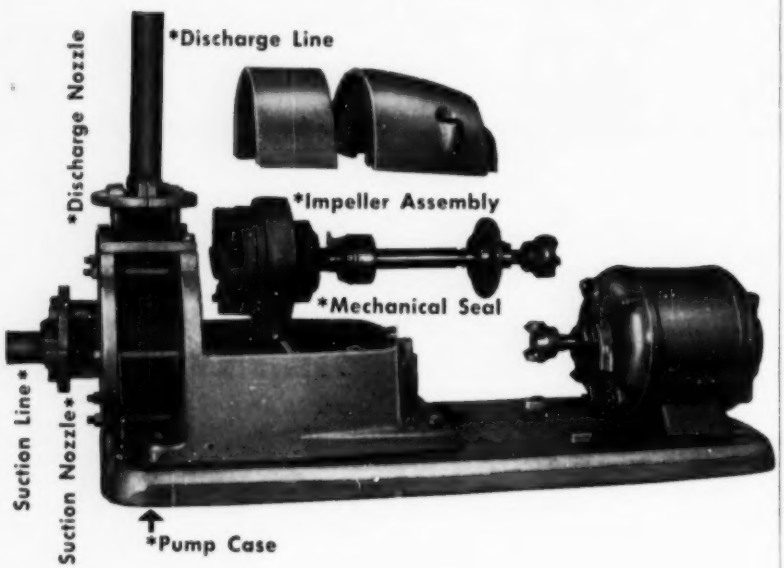
THEY Resist the sharpest corrosives

Maintain chemically tight seal

Provide maximum clean flow

Last longer under severe conditions

Provide solid Impervious Graphite parts (not a thin facing) at all contacting surfaces *



AND! Disassemble for inspection or repair without disturbing the processing lines.

ASK FOR NEW DESCRIPTIVE BULLETIN

Falls Industries, Inc.

AURORA ROAD · SOLON, OHIO

NEWS

(*Continued from page 64*)

UNIVERSITIES RECEIVE GRANTS FROM INDUSTRY

Among the industrial firms announcing academic fellowships for 1953-54 are American Cyanamid Co., Coats & Clark, Inc., The M. W. Kellogg Co., and Shell Oil Co.

A 15% increase in the Shell research and fellowship programs was announced last month, resulting in an increase of fundamental research grants from 12 to 14 and of fellowships from 45 to 48. Total cost of the program will be $177,000. Research grants, at $5,000 each, are made directly to university science departments to aid them in conducting basic research in chemical engineering, chemistry, mechanical engineering, geology, metallurgy corrosion, physics, and engineering mechanics.

Coats & Clark has made available three fellowships for graduate study and research in the field of textile technology at Massachusetts Institute of Technology. Holders of bachelor's degrees in chemical engineering and other fields of engineering and science are eligible for these awards of $1,800 a year.

American Cyanamid's program this year includes seventeen graduate fellowships in chemical engineering and chemistry. The fellowships are awarded to graduate students commencing their final predoctoral year of study and carry a stipend of $1,500 plus full tuition and incidental laboratory fees. They also include $300 for unrestricted use by the student's department.

The M. W. Kellogg grants are to be offered annually to selected employees of the company and its subsidiaries, allowing them to attend full time at an accredited college while maintaining their regular base pay. The Morris W. Kellogg Scholarships, named for the company's founder, consist of one grant for the pursuance of a master's degree and two grants for bachelor's degrees each year.

G. M. ENGINEERING JOURNAL MAKES DEBUT

Publication of a magazine to present General Motors technical developments to educators and engineering college students was announced late last month by Paul Garrett, General Motors vice-president in charge of public relations.

Known as the GM Engineering Journal, it will appear bimonthly during the school year and once during the midsummer months. The new project handled by the Educational Relations Section of Public Relations Department is headed by Kenneth A. Meade. Editor of the journal is Arvid F. Jouppi.

B.L.S. STUDIES DEMAND FOR CHEMICAL ENGINEERS

A study of factors affecting the demand for chemical engineers and chemists in industry is being made by the Bureau of Labor Statistics at the request of the Department of Defense. Representatives of the Bureau visited selected firms in the chemical, rubber, and petroleum industries during May, June, and July to obtain appraisals of how their requirements for scientific and technical personnel are determined.

To arrive at a statistical analysis of the factors influencing short- and long-range demand, data will be requested on employment, research expenditures, and related factors.

"Although the gravity of the scientific manpower situation is widely recognized," Ewan Clague, Commissioner of Labor Statistics, said, "no adequate information exists on the current and prospective demand for scientific personnel. Such information is needed by the Government in planning scientific research programs and in developing policies with regard to Selective Service deferments and call-up of reservists." This information, it was pointed out, would also be of use to professional societies, vocational-guidance advisers, and private industry. Additional news on this subject will be found on page 64 of this issue.

BURDELL DISCUSSES ROLE OF TECHNICAL SCHOOL

A need for broader objectives in the curriculum of technical institutes to prepare students for living as well as for earning a living was stressed by Edwin S. Burdell, president of The Cooper Union, at the annual dinner of the Technical Institute Division of the American Society for Engineering Education.

"Motivation for participation in a democratic society is just as much an obligation of educators as training to perform well on the job," President Burdell said. "We simply can't take it for granted that young citizens today will be able to find their way around in human relations in the shop, community, or home."

Dr. Burdell added that the growth of technical institutes had been the greatest single innovation in American education in the second quarter of the twentieth century and compared their growth to the increase in high school education during the first quarter of the century. He pointed out also that the increasing use of automatic machinery was creating a demand for more technical operating personnel and said that public school systems should be encouraged to expand their technical programs to alleviate the present engineering manpower shortage.

You're looking at a polished section cut from a Duraspun Centrifugal Casting...a casting with 12-14% chromium. It tells better than words of the high quality of Duraspun Centrifugal Castings.

You get a fine, dense, uniform grain structure. Possible air pockets and blow holes are eliminated. Tensile strength is higher than with static castings.

Order Duraspun if you need pipe or tubing. Sizes run up to 15 feet in length; up to 32 inches OD; and down to ¼ inch wall thickness. Odd shaped pieces can be produced providing a circular hole passes uniformly down the center. These, of course, require specially designed casting forms.

If, before ordering or asking us to quote, you would like to know more about our work and facilities, send for our Catalog 3150.

THE DURALOY COMPANY
Office and Plant: Scottdale, Pa. • Eastern Office: 12 East 41st Street, New York 17, N.Y.

Detroit Office: 23906 Woodward Avenue • Pleasant Ridge, Mich.
Atlanta: J. M. TULL Metal & Supply Co.
Chicago: F. O. NELSON 332 S. Michigan Avenue
METAL GOODS CORP.: Dallas • Denver • Houston • Kansas City • New Orleans • St. Louis • Tulsa

FEON

DUST COLLECTOR FABRICS for Hot or Corrosive Materials

Hot acid fumes up to 300°F, chlorine, and smelter exhausts are just a few of the materials that are handled by these new FEON Orlon fabrics. Long life, because of high strength and chemical resistance, gives remarkable savings in "tough" dust collecting application.

Other FEON fabrics are equally thrifty. One user reduced cloth costs over 50% . . . merely by switching to FEON Dynel.

FOR ANY TYPE OF EQUIPMENT

FEON weaves to handle any size or type of dust particles are available as yard goods, or fabricated into elements for any type of equipment. On any tough dust collecting or filtering job—switch to FEON and save.

FILTRATION FABRICS DIVISION
FILTRATION ENGINEERS, INC.
155 Oraton St., Newark 4, N. J.

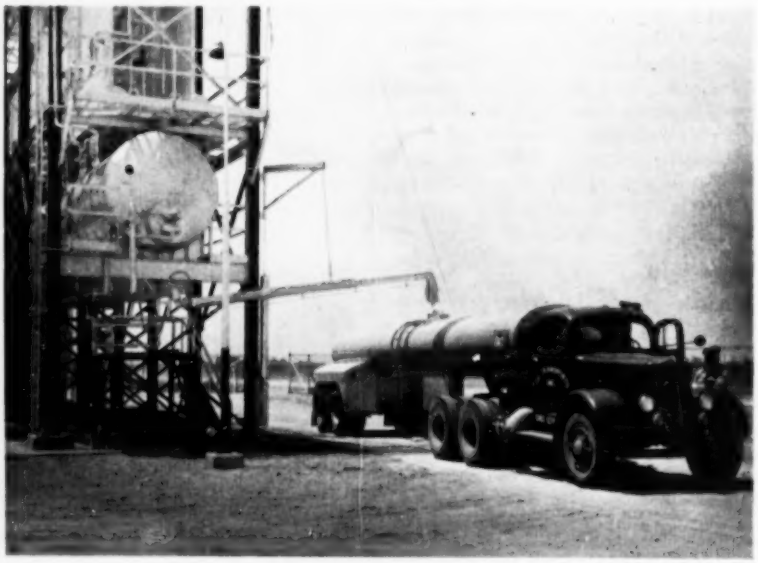
SULFUR UNIT COMPLETES 100% USE OF WASTE GAS

Complete utilization of casing-head gas has been realized by Gulf Oil Corp. with successful operation of its sulfur-recovery unit at Waddell, Texas. In its first year of operation the unit, rated at 44,000 lb. daily, produced 12,750,000 lb. of sulfur.

The chief significance of the Waddell operation lies in its conversion of the remainder of what was once an oil-field waste into a valuable product. The original plant, erected in 1949, converts casing-head gas into natural gasoline, propane, butane, and residue gas. Of these products, natural gasoline is introduced into the company's crude oil, butane and propane are marketed as bottled gas and for chemical uses, and the residue gas is sold for direct consumption.

The only portion of casing-head gas not previously used at Waddell was the acid gas that was removed from the main stream by desulfurizing. The resulting sulfurous gas was burned off in flares. The new sulfur unit converts this previously wasted gas into two streams. One of these is fed to the boiler fuel boxes. What remains after burning recombines with the original stream, from which sulfur is then recovered in the presence of a catalyst. A single-phase, modified Claus process is used.

The unit's entire production is currently purchased, for fertilizer and insecticides. The product is loaded into trucks at 255° to 265° F., and, since the sulfur drops in temperature only 1°/hr. and does not solidify above 230° F., there is ample time to ensure its delivery as a liquid. This delivery method eliminates the usual sulfur storage and flaking operations.



Sulfur storage and loading facilities at the Gulf Oil Corp. plant at Waddell, Texas. Molten sulfur is loaded into a truck by a gravity method, and the slow rate of solidification permits delivery in a liquid state, thus eliminating additional storage requirements.

PLACEMENT AID FOR ENGINEERS IN SERVICE

The Engineering Manpower Commission of the Engineers Joint Council has announced that industrial firms, banned from recruiting returning engineers at military separation points by the Defense Department, will make every effort to interview engineers through facilities offered at college placement bureaus and through the four offices of the Engineering Societies Personnel Service, Inc., which are located at 8 West 40 St., New York City, 84 Randolph St., Chicago; 100 Farnsworth Ave., Detroit; and 57 Post St., San Francisco.

There are many engineering jobs available for qualified men, the E.M.C. stated, and "to prevent technological talent from straying into other fields," the Commission has mailed placement information to engineers who could be located in the services. This information may also be obtained in convenient card form from E.M.C., 29 West 39 St., New York City.

LOCAL SECTION

A dinner meeting, ending the 1952-53 season of the Rochester Section, was held May 20 at Lorenzo's Restaurant. A. S. Rupp, associated with Oak Ridge National Laboratory, Oak Ridge, Tenn., left some interesting thoughts with his audience on radioisotopes, which, he claimed, could be much more widely used than they now are to provide engineering facts. W. F. Kaiser, reporter, sent in the names of the officers elected for the 1953-54 season. They are as follows: Irving Siller, Pfaudler's, chairman; W. F. Kaiser, Kodak Park Works, vice-chairman; W. E. Eilinger, Kodak Park Works, secretary; O. J. Britton, Pfaudler's, treasurer; I. S. Bradley, Kodak Park Works, and Earl Costich, Mixing Equipment Co., directors.

Forty-six members and guests of the Atlanta Section met on the Georgia Tech campus to hear R. J. Raudebaugh, director of the school of chemical engineering of Georgia Tech, discuss the research under way in his department. He introduced members of his staff who talked briefly on their fields of interest. H. H. Cudd, acting director, Engineering Experiment Station, talked on the objectives of the Experiment Station. An interesting feature of the meeting, according to Reporter Sineath, was the guided tours through the Georgia Tech School of Chemical Engineering and Engineering Experiment Station. At the former the Micromeretics Laboratory, Metallurgical Laboratory, and the liquid air plant were the special points of interest and at the latter the groups were shown the liquid cyclone, sanitary and biological laboratories, X-Ray diffraction and electron microscopy applications. The meeting was adjourned after a bull session in the conference room of the Station.

The Dallas (Tex.) Chemical Engineers' Club organized at the beginning of this year has held five meetings with an average attendance of 40. Harold A. Blum, secretary-treasurer of the Club, reported that at the May meeting R. Reed, John Zink Co., gave a talk titled "Combustion and Heat Transfer." Officers of the Club elected at the first meeting are: R. A. Graff, chairman; R. L. Purvin, vice-chairman; H. A. Blum, secretary-treasurer. Those on the executive committee are C. F. Tears, O. Baker, and H. A. Koch, Jr.

Members of the El Dorado Section went on a plant trip through the Commercial Solvents Corp.'s ammonia-methanol installation at Sterlington. Edward White, reporter, writes that G. E. Hines, superintendent of the Terre Haute plant of Commercial Solvents, addressed the group on dextron production.

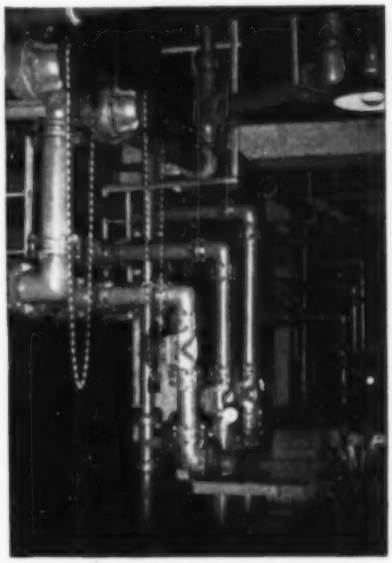
The Oklahoma Section heard J. W. McCaslin, health physicist, Atomic En-

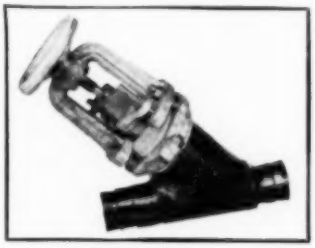
265° F.
PLUS A WIDE SAFETY MARGIN
with HAVEG CORROSION RESISTANT PIPE

Backed by twenty years of experience in building plastic corrosion-resistant equipment, the Haveg Corporation offers a superior line of chemical pipe and fittings that withstand 265°F. plus a wide margin of safety.

More than our laboratory tests and a few installations have established this figure. It comes from thousands of plant engineers who have successfully used Haveg pipe where the liquids handled get really hot and corrosive. Now, improvements in manufacture make genuine Haveg pipe available for immediate shipment. Why take a substitute "plastic" pipe when service-proven Haveg can give the long range economies of quality?

(Haveg is a moldable, thermosetting plastic material made from acid-digested asbestos and synthetic resin selected for specific service with a broad list of corrosive gases and liquids. Pipe made from Haveg is extremely resistant to thermal shock, seldom requires insulation, and is easily installed. Machining, alterations, repairs can be made on the spot.)





HAVEG VALVES

Skilled Haveg molders have produced a variety of valve bodies and parts to give freedom from corrosion and long operating life. Escape potential valve troubles by buying Haveg y-valves and diaphragm valves which are smooth-molded, exactingly machined and tested in the Marshallton factory. Haveg has valves in stock and will work with you on special designs.

HAVEG DUCT

Highly corrosive gases and fumes should be safely handled by a Haveg system using molded, versatile duct, fume hoods, bifurcators, fan housings, fittings, weather caps. Act now. Write for 64-page Technical Bulletin F-6 showing sizes, types of Haveg fume line equipment.

CALL A HAVEG SALES ENGINEER FOR INFORMATION

The Haveg Corporation has its factory at Marshallton, Delaware. Telephone: Wilmington 3-8884. District sales offices are located in Atlanta, Chicago, Cincinnati, Cleveland, Detroit, Hartford, Houston, Los Angeles, Seattle, and St. Louis. Write for Technical Bulletin F-6 and call your Haveg Sales Engineer for advice, service, technical and delivery data.

PUMPS TANKS PIPE

HAVEG CORROSION-RESISTANT EQUIPMENT

HAVEG CORP. • A SUBSIDIARY OF CONTINENTAL-DIAMOND FIBRE CO.

TRADE MARK REG. U.S. PAT. OFF. MARSHALLTON, DELAWARE

FUTURE MEETINGS AND SYMPOSIA OF A.I.Ch.E.

Chairman of the A.I.Ch.E. Program Committee

Loren P. Scoville, Jefferson Chemical Co. 260 Madison Ave., New York 16, N. Y.

MEETINGS

San Francisco, Calif., Fairmont Hotel, Sept. 13-16, 1953.
TECHNICAL PROGRAM CHAIRMAN: R. W. Moulton, Head, Dept. of Chem. Eng., University of Washington, Seattle, Wash.

Annual—St. Louis, Mo., Hotel Jefferson, Dec. 13-16, 1953.
TECHNICAL PROGRAM CHAIRMAN: J. J. Healy, Jr., Assist. to V. P., Monsanto Chemical Co., 1700 S. 2nd St., St. Louis 4, Mo.

Washington, D. C., Statler Hotel, March 8-10, 1954.
TECHNICAL PROGRAM CHAIRMAN: George Armistead, Jr., Consult. Chem. Eng., George Armistead & Co., 1200 18th St. N.W., Washington 6, D. C.

Springfield, Mass., Hotel Kimball, May 16-19, 1954.
TECHNICAL PROGRAM CHAIRMAN: E. B. Fitch, Asst. to Res. Dir., The Dorr Co., Westport, Conn.

Ann Arbor, Mich., Univ. of Mich., Ann Arbor, Mich., June 20-25, 1954—Conference on Nuclear Engineering.
TECHNICAL PROGRAM CHAIRMAN: D. L. Katz, Chairman, Dept. of Chem. and Met. Eng., Univ. of Mich., 2028 E. Eng. Bldg., Ann Arbor, Mich.

Glenwood Springs, Colo., Hotel Colorado, Sept. 12-16, 1954.
TECHNICAL PROGRAM CHAIRMAN: Prof. C. H. Prien, Dept. of Chem. Eng., Univ. of Denver, Denver 10, Colo.

Annual—New York, N. Y., Statler Hotel, Dec. 12-15, 1954.
TECHNICAL PROGRAM CHAIRMAN: G. T. Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.
ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Lake Placid, N. Y., Lake Placid Club, Sept. 25-28, 1955.
TECHNICAL PROGRAM CHAIRMAN: L. J. Coulthurst, Chief Proc. Designer, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

SYMPOSIA

Ion Exchange
CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.
MEETING—San Francisco, Calif.

Mixing
CHAIRMAN: J. H. Rushton, Dept. of Chem. Eng., Illinois Inst. of Tech., Chicago, Ill.
MEETING—San Francisco, Calif.

Transport Properties
CHAIRMAN: J. L. Franklin, Res. Assoc., Humble Oil & Refining Company, Baytown, Texas.
MEETING—San Francisco, Calif.

Applied Thermodynamics
CHAIRMAN: W. C. Edmister, Calif. Res. Corp., 576 Standard Ave., Richmond, Calif.
MEETING—San Francisco, Calif.

Fluid Mechanics
CHAIRMAN: R. W. Moulton, Head, Dept. Chem. Eng., Univ. of Washington. Seattle, Wash.
MEETING—San Francisco, Calif.

Distillation
CHAIRMAN: D. E. Holcomb, Dean of Eng., Texas Technological College, Lubbock, Tex.
MEETING—St. Louis, Mo.

Dust and Mist Collection
CHAIRMAN: C. E. Lapple, Dept. of Chem. Eng., Ohio State University, Columbus 10, Ohio.
MEETING—St. Louis, Mo.

Drying
CHAIRMAN: L. E. Stout, Dept. of Chem. Eng., Washington Univ., St. Louis 5, Mo.
MEETING—St. Louis, Mo.

Use of Computers in Chemical Engineering
CHAIRMAN: John R. Bowman, Head, Dept. of Res. in Phys. Chem., Mellon Institute of Industrial Research, Pittsburgh 13, Pa.
MEETING—St. Louis, Mo.

Heat Transfer
CHAIRMAN: D. L. Katz, Chairman (Address: See Ann Arbor Meeting).
MEETING—St. Louis, Mo.

Carbonization
CHAIRMAN: R. S. Rhodes, Asst. Mgr., Prod. Dept., Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
MEETING—St. Louis, Mo.

Industrial Waste Disposal
CHAIRMAN: K. S. Watson, Coordinator, Waste Treatment, Mfg. Facilities Serv. Dept., Gen'l. Electric Co., 202 State St., Schenectady, N. Y.
MEETING—St. Louis, Mo.

Patents
CHAIRMAN: W. C. Asbury, V. P., Std. Oil Dev. Co., 15 W. 51st St., New York 19, N. Y.
MEETING—Washington, D. C.

Chemical Engineering in the Fertilizer Industry
CHAIRMAN: G. L. Bridger, Head, Dept. Chem. & Mining Eng., Iowa State College, Ames, Iowa
MEETING—Washington, D. C.

Nuclear Engineering
CHAIRMAN: D. L. Katz, Chairman (Address: See Ann Arbor Meeting).
MEETING—Ann Arbor, Mich.

Reaction Kinetics
CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.
MEETING—New York, N. Y.

Liquid Entrainment and Its Control
CHAIRMAN: H. E. O'Connell, Ethyl Corp., P. O. Box 341, Baton Rouge, La.

Absorption
CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

Centrifugation
CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Nucleation Processes
CHAIRMAN: E. L. Piret, Dept. Chem. Eng., Univ. of Minn., Minneapolis 14, Minn.

Authors wishing to present papers at a scheduled meeting of the A.I.Ch.E. should first query the Chairman of the A.I.Ch.E. Program Committee, Loren P. Scoville, with a carbon copy of the letter to the Technical Program Chairman of the meeting at which the author wishes to present the paper. Another carbon should go to the Editor, F. J. Van Antwerpen, 120 East 41st Street, New York 17, N. Y.

ergy Division, Phillips Petroleum Co., Idaho Falls, Idaho, speak on "Generation and Disposal of Radioactive Materials in the Atomic Energy Program." At a previous meeting held in Bartlesville, Paul R. Schultz, manager of the economics department, Stanolind Oil and Gas Co., covered the report of the National Petroleum Council on synthetic fuels. F. Morgan Warzel reports that the review covers estimates for the production of synthetic fuels by three methods—coal hydrogenation, modified Fischer-Tropsch, and the processing of oil shale.

W. E. Keppler, chairman of the Central Pennsylvania Chemical Engineers' Club, reports on the concluding session of a successful spring program, when John Seabrook, Seabrook Farms, Inc., talked on waste disposal in industry. At a previous meeting, J. T. Bergen, Armstrong Cork Co., gave an address titled "Calendering of Plastics."

Members of the Chemical Engineers Club of Washington were all agog over the annual outing, when the good ship "The Anna and Helen" pulled out from Capt. Nieberding's wharf at Edgewater, Md., for a day's fun on the Chesapeake. Fishing, sailing, bathing, loafing and a general good time were all on the agenda.

At the annual banquet of the Charleston Section held at the Kanawha Country Club, 145 members heard Frank E. Serry, manager, Pittsburg sales office, General American Transportation Corp., describe the problems encountered during the construction of a food-processing plant in the hinterland of Brazil. The following officers for 1953-54 were elected by mail ballot. B. T. Woodruff, Du Pont, chairman; J. R. Kernan, Carbide, vice-chairman; A. C. Hyde, Du Pont, secretary; R. E. Ross, Westvaco, treasurer; E. J. Cannon, Carbide, member-at-large, executive committee. A. G. Draeger writes that the dinner meeting was preceded by an afternoon of golf and a cocktail hour.

The grand finale of the season for the Central Ohio Section was a ladies' night at Hoffman Gardens. After a social hour and dinner, Paul Noel, assistant special agent, F.B.I., in charge of the Steubenville, Ohio, office discussed "F.B.I. and Its Activities." About sixty persons attended and the ladies took part with considerable gusto in the discussion that followed, so reports G. F. Sachsel. At a previous meeting J. H. Blodgett, superintendent of the Columbus Sewage Treatment Works, discussed "Sewage Treatment in Columbus." Mr. Blodgett, a graduate of M.I.T., has been associated with the City of Columbus since 1928 in various capacities, covering the design, construction, and operation of sewage-disposal plants.

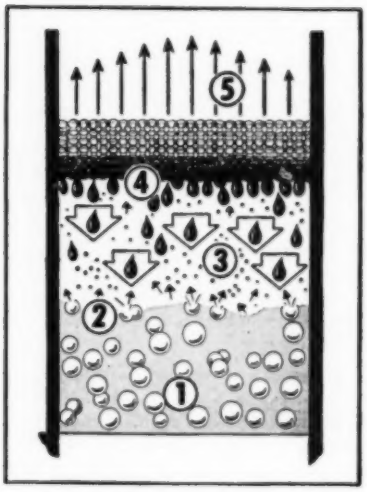
(Advertisement)

Pads of Knitted Wire Mesh Wipe Out Liquid Entrainment

Removal of the liquid carry-over which is present in a wide range of processing operations is being secured, effectively and economically, by using pads made from multiple layers of knitted wire mesh.

These pads combine, within a few inches of depth, large wire surface area with an unusually high free volume—97 to 98%—made up of a multiplicity of unaligned asymmetrical openings. Installed within a vessel, these pads offer minimum restriction and pressure drop, yet it is impossible for a gas to pass through without continually changing direction and forcing impingement of the entrained liquid droplets upon the wire surface.

How These Pads Work



A gas generated in or passing through a liquid (1), carries with it, as it bursts from the liquid surface (2), a fine spray of liquid droplets. These entrained droplets are carried upward by the rising gas stream (3).

As this gas passes through the pad, the droplets impinge on the extensive wire surface (125 square feet per cubic foot of pad volume). Droplets accumulate on the wire surface and form large drops of liquid which break away (4) from the wire mesh and fall back against the gas stream. The gas (5) passes on, freed from liquid entrainment. The liquid is returned.

Availability

Since these pads, known as METEX MIST ELIMINATORS, can be knitted of practically any metal or alloy available in wire form, effects of corrosion can be minimized. A builetin giving detailed information is available on request from the manufacturer, Metal Textile Corporation, Roselle, N. J.

T. J. Carron has sent in the names of the new officers of the Detroit Section for the fiscal year beginning July 1, 1953. They are as follows: T. J. Carron, Ethyl Corp., Detroit, chairman; P. A. Lenton, Wyandotte Chemicals, Wyandotte, vice-chairman; R. E. Cavanaugh, Sno-Flake Products Co., Detroit, secretary; J. Adinoff, Parke Davis and Co., Detroit, treasurer; H. G. Donnelly, Wayne University, Detroit, member-at-large, board of directors.

A recent activity of the South Texas Section was the inspection trip through the Goodyear Synthetic Rubber Corp. in Houston. At the dinner held later, Prof. R. G. Folsom, chairman of the department of chemical engineering, University of California, talked on recent developments and performance data relative to jet propulsion. Neil H. McKay, Jr., writes that during the summer there will be a cessation of activities and that the only event on the agenda now is the family picnic scheduled for September, and the Eighth Annual Technical Meeting scheduled for October.

Two speakers addressed the final meeting of the Cleveland Section, namely, J. W. Muntz, assistant general manager, Painesville plant, Diamond Alkali Co., whose subject was "Alkali in Our Daily Lives," and C. F. Ruebensaal, manager, commercial development division, U. S. Rubber Co., whose talk was titled "The Synthetic Rubber Industry." Lutz's Hotel in Painesville was the locale of this meeting since, as Charbonnet, the reporter of the Section states, "since a rather large percentage of our membership lives quite far from our usual meeting-place, we thought that for once the majority could go to a place more convenient for the minority."

The student chapter at the University of California was host to the Northern California Section at a dinner held at International House on the Berkeley campus. Those attending heard a talk by Paul L. Kirk, professor of biochemistry and criminalistics, describe his work in the field of scientific crime investigation.

A subsequent meeting was held at the Engineers' Club in San Francisco. The approximately 110 members and guests attending heard a talk on "Preparing Engineers for Management." The speaker, Douglas Watson of McKinsey and Co., described the characteristics that are essential to successful administrators.

The Section officers recently elected, who will assume their duties in the fall, are: E. B. Chiswell, California Research Corp., Richmond, Calif., chairman; G. B. Zimmerman, Bechtel Corp., San Francisco, vice-chairman; T. E. Drisko, Dow Chemical Co., Pittsburg, secretary-treasurer. A. Eriksen, Girdler Corp., San Francisco; N. K. Hiester, Stanford Res. Inst., Palo Alto, and J. A. Samaniego, Shell Dev. Co., Emeryville, are executive committeemen.

DOW CORNING
ANTIFOAM A

Add a trace of Dow Corning Antifoam A and use the space you've been wasting on foam.

FOR EXAMPLE:

- *Antifoam A permits molasses processor to increase standard load from 18 to 24 tons . . .*
- *Antifoam A enables textile finisher to double color yield on vat dyes . . .*
- *Antifoam A ups vacuum concentration capacity 60% for food processor . . .*

That's what we mean when we say foam's a thief. And you don't have to put up with it any more. Both Dow Corning Antifoam A and the new water-dispersible Antifoam AF Emulsion are effective at very low concentrations against a wide variety of aqueous and non-aqueous foamers. They are odorless, tasteless and harmless physiologically. Dow Corning Antifoam A can be used as received, mixed with one of the foaming ingredients or dispersed in a solvent for industrial application. Antifoam AF Emulsion is equally versatile and easily dispersed in water.

see for yourself!

mail coupon TODAY for **free sample**

DOW CORNING SILICONES

Dow Corning Corporation
Midland, Mich., Dept. CS-7,

Please send me data and a free sample of—

☐ Dow Corning Antifoam A or
☐ Dow Corning Antifoam AF Emulsion

NAME_____
COMPANY_____
ADDRESS_____
CITY_____ ZONE____ STATE_____

A feature of the Southern Regional Conference of A.I.Ch.E. Student Chapters was the banquet address given by Paul C. Young (above), professor of psychology at Louisiana State University, Baton Rouge, where the convention was held. Ninety students, representing fourteen colleges, participated in events, which included a smoker and plant trips. Visits were made to the Ethyl Corp., Esso Standard Oil and Esso Labs., or Kaiser Aluminum and Chemical Co. A panel discussion titled "Opportunities for Chemical Engineers in Industry" covering petrochemical and petroleum industries, heavy chemicals, and pulp and paper; technical papers by students; election of officers; an informal dance; and the presentation of awards rounded out the program. Winners of the technical paper presentations were: first place, Robert Weaver, Tulane University; second place, Thomas Bossler, University of Louisville; third place, R. R. Simms, Jr., Tulane University. Next year the convention will be held at Tulane.

DISTRIBUTION OF ENGINEERS IN INDUSTRY

Preliminary Government data on classification of engineers were recently made public by the Engineering Manpower Commission of the Engineers Joint Council. Based largely on the 1950 Census, the figures are indicative but are not official. The total number of professional engineers reported in 1950, according to the E.J.C. report, was about 519,000; of these 414,000 were in private industry, while 93,000 were in Government.

Private-Industry Distribution, thousands

Manufacturing (all types)	230	Education	14
Trade and services	76	Mining	11
Construction	44	Transportation	11
Communications and utilities	40	Agriculture	1

Engineering Classification, %

Civil	24	Chemical	6
Mechanical	19	Metal and mining	5
Electrical	18	Aeronautical (80% in industry, 13% in Government)	4
Industrial	9	All others	16

Distribution by Classification, %

	Mechanical	Civil	Electrical	Chemical
Manufacturing	60	10	33	75
Communications and utilities	5	5	30	3
Construction	8	25	6	3
Transportation	3	4	2	1
Mining	1	1	1	3
Government	7	40	8	3
Other	16	15	20	12

LOCAL SECTION NEWS

(*Continued from page 71*)

A Ladies' night was sponsored by the Knoxville-Oak Ridge Section at the S and W Cafeteria in Knoxville, Tenn. Stuart Fonde, a building contractor and building material supplier of Knoxville, gave a talk titled "The Modern Medium-Priced Home."

The St. Louis Section recently met at Missouri Athletic Club in St. Louis for "Old Timers Night" with sixty-one in attendance. H. E. Wiedemann ("Wiedy") reminisced briefly on the old timers who founded the St. Louis Section about twenty-five years ago.

George E. Mylonas, head of the department of art and archaeology, Washington University, told of archaeological finds he made in Greece while supervising excavations there last year. Reporter Kerlin states that he himself learned that archaeology is a stern scientific discipline in Greece, and that only the most expert field archaeologists may disturb the relics of antiquity.

The Pittsburgh Section held its eighth and final dinner meeting of the 1952-53 year at the Royal York Apartment. Included in the evening's events was the election of officers with results as follows: W. M. Trigg, chairman; J. McAfee, vice-chairman; J. R. West, secretary, and J. F. Joseph, treasurer.

Robert L. Wehrli, assistant director of research, Reaction Motors, Inc., Rockaway, N. J., spoke on "Elements of Rocket Propulsion." Messrs. West, Morrissey and Black reported that the audience, numbered approximately 100 people.

At a meeting of the Southern California Section held June 16, S. G. Sevougian reported that George Perkins, general director of products and application, Reynolds Metal Co., discussed some of the latest developments in aluminum products and showed a technicolor movie "Pigs and Progress."

At the eighth meeting of the Northeastern New York Section held at Troy, N. Y., Charles M. Cooper, Du Pont Co., spoke on "Tools versus Information." His talk dealt largely with education and was provocative. R. H. Simon discussed the need of an amendment to the Taft-Hartley Act as it affects professional societies.

The last meeting of this section featured a talk and discussion on "Chemical Engineering of Antibiotic Manufacture" by Eric Braun of Merck & Co. Harry H. Steinhauser, Jr., reported both these meetings.

Summer and vacation periods do not necessarily mean a cessation of news from local sections. A tapering off is expected but the August and September issues will contain all the items of interest that reach this office on time.

—H.R.G.

PEOPLE

Lauren B. Hitchcock, who resigned recently as president of the National Dairy Research Laboratories, Inc., has announced the opening of his office in the Chemists Building, New York, for consulting practice. Dr. Hitchcock will specialize in problems of administration of research and development in industry. He brings to his consulting practice experience in teaching at the University of Virginia and industrial affiliations with Hooker Electrochemical Co., Quaker Oats Co., and lately with National Dairy Products Corp., as its director of research and development and president of its subsidiary, National Dairy Research Labs.

Fabian Bachrach

W. R. MARSHALL HONORED

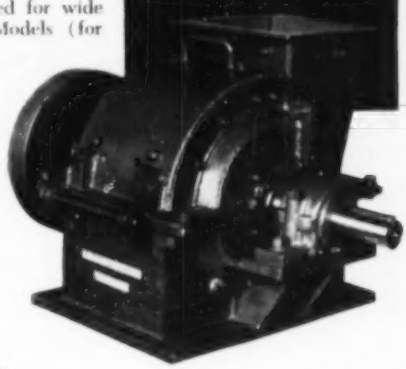
William R. Marshall, Jr., now associate professor of chemical engineering, University of Wisconsin, has been named associate dean of the College of Engineering and associate director of the Wisconsin Engineering Experiment Station. Dr. Marshall has been on the faculty of the University of Wisconsin chemical engineering department since 1947. Prior to this assignment he served in the experimental station of the Du Pont Co., Wilmington, Del. A Canadian by birth, Dr. Marshall received his Ph.D. in chemical engineering from Wisconsin in 1941.

Herbert T. Kalmus, president and general manager of Technicolor Motion Picture Corp., Hollywood and New York, has been named a member of the board of directors of Stanford Research Institute. Dr. Kalmus, a chemical engineer, is also chairman of the board of Technicolor, Ltd. of London. Educated at M.I.T., Zurich, and Berlin, and a one-time professor of physics and electrochemistry at Queens University, Dr. Kalmus has headed Technicolor Motion Picture Corp. and Technicolor, Inc., since their inceptions in 1915 and 1922, respectively. He has been president of Kalmus, Comstock & Westcott, Inc., the Exolon Company of New York and Canada and of the American Protein Corp., Boston.

PRECISE REDUCTION for EXPERIMENTAL LABS, PILOT PLANTS, TEST RUNS

American No. 13 Series CRUSHERS

Designed for capacities beyond those of lab mills and below those required for large-scale crushing operations. Effectively used for wide range of materials. Up-Running Models (for maximum fines); Down-Running (for minimum fines). Equipped with rings or any of a full variety of hammers. Backed by over 40 years' experience in building reduction equipment. Write for Catalog on "13" Series Crushers.



FREE Laboratory Service

Send material sample for test reduction and recommendations for reduction equipment. No obligation.

American PULVERIZER COMPANY

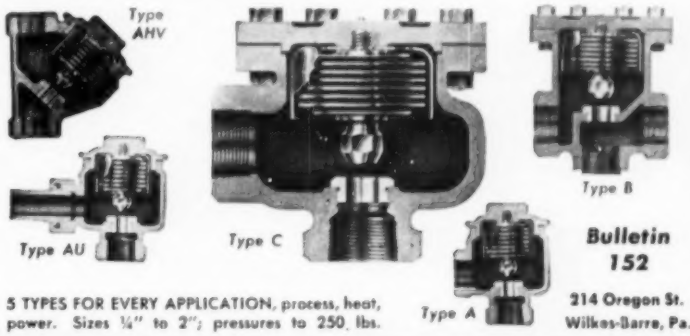
Originators and Manufacturers of Ring Crushers and Pulverizers

1215 MACKLIND AVE. • ST. LOUIS 10, MO.

Nicholson Steam Traps

CUT HEAT-UP TIME 48%

A large processor recently reduced the heating cycles of kettles from 105 min. to 50-60 min., by substituting Nicholson thermostatic steam traps for a mechanical type. This effected a gratifying production increase of 37%. Reasons for Nicholson's faster heat transfer: operate on lowest temperature differential; 2 to 6 times average drainage capacity; maximum air venting. To learn why an increasing number of leading plants are standardizing on Nicholson thermostatic traps send for our catalog.



5 TYPES FOR EVERY APPLICATION, process, heat, power. Sizes ¼" to 2"; pressures to 250 lbs.

Bulletin 152

214 Oregon St. Wilkes-Barre, Pa.

W. H. NICHOLSON & CO.

TRAPS · VALVES · FLOATS

CHEMICAL ENGINEERING PROGRESS

monograph and symposium series

SYMPOSIUM SERIES (8½ by 11, paper covered)

1. **Ultrasonics—two symposia**
   (87 pages; $2.00 to members, $2.75 to nonmembers)
2. **Phase-Equilibria—Pittsburgh and Houston**
   (138 pages; $3.75 to members, $4.75 to nonmembers)
3. **Phase-Equilibria—Minneapolis and Columbus**
   (122 pages; $3.75 to members, $4.75 to nonmembers)
4. **Reaction Kinetics and Transfer Processes**
   (125 pages; $3.75 to members, $4.75 to nonmembers)
5. **Heat Transfer—Atlantic City**
   (162 pages; $3.25 to members, $4.25 to nonmembers)

MONOGRAPH SERIES (8½ by 11, paper covered)

1. **Reaction Kinetics by Olaf A. Hougen**
   (74 pages; $2.25 to members, $3.00 to nonmembers)

Price of each volume depends on number printed. Series subscriptions, which allow a 10% discount, make possible larger runs and consequently lower prices.

— — — — — — — — — MAIL THIS COUPON — — — — — — — — —

CHEMICAL ENGINEERING PROGRESS
120 East 41 Street, New York 17, N. Y.

☐ Please enter my subscription to the CEP Symposium and Monograph Series. I will be billed at a subscription discount of 10% with the delivery of each volume.

Please send:

☐ copies of *Heat Transfer—Atlantic City.*
☐ copies of *Reaction Kinetics and Transfer Processes.*
☐ copies of *Phase-Equilibria—Minneapolis and Columbus.*
☐ copies of *Phase-Equilibria—Pittsburgh and Houston.*
☐ copies of *Ultrasonics.*
☐ copies of *Reaction Kinetics.*

☐ Bill me. ☐ Check enclosed (add 3% sales tax for delivery in New York City).

Name.....

Address.....

.....

☐ Active ☐ Associate ☐ Junior ☐ Student ☐ Nonmember

J. L. BENNETT RETIRES

Greystone-Stoller Corp.

J. Leroy Bennett, President of the American Institute of Chemical Engineers (1943) and manager of chemical operations since 1931 for the explosives department, Hercules Powder Co., Wilmington, Del., has retired after forty-six years with the company. He has held many positions in Hercules, including supervision of various chemical operations at explosives plants in Missouri, Utah, and California, and for the last twenty-two years supervision of all heavy chemical operations for the company's explosives department.

First associated with the Independent Powder Co., Carthage, Mo., he joined Hercules in 1914, at Hercules, Calif. He served as assistant acid supervisor there, and as acid supervisor at Bacchus, Utah, before going to the chemical department of Hercules at Wilmington in 1919. Mr. Bennett has also served as chairman of the Philadelphia-Wilmington Section of A.I.Ch.E.

E. T. Harding has been appointed assistant to the general manager of Corn Products Chemical Division at Argo, Ill. Mr. Harding had previously been employed in the engineering department of Corn Products Refining Co. He received his B.S. degree from the University of Illinois in 1944.

Paul W. Bachman was recently elected vice president of The Davison Chemical Corp., Baltimore, Md. He was formerly director of research and development and will continue in charge of these activities. Dr. Bachman joined Davison in 1949 as manager of development planning. He has been active in technical aspects of the current Davison plant expansion program. He has successively held research positions with Du Pont Co., General Chemical Co., Victor Chemical Works and again with General Chemical Co. Immediately prior to joining Davison he was with Commercial Solvents Corp.

Sam Tour, general manager of Sam Tour & Co., Inc., New York, has been retained by the Icelandic Government to investigate means of preventnig corrosion in municipal heating systems which derived their heat from underground hot water springs. This project is financed by the productivity and technical assistance division of the Mutual Security Administration.

S. G. Bankoff was recently named head of the chemical engineering department, Rose Polytechnic Institute, Terre Haute, Ind., after serving as acting head for the past year. He has been with Rose Polytechnic since 1948. At the beginning of his career Dr. Bankoff worked for Sinclair Refining Co., at East Chicago, Ind. Subsequently, he was associated with Du Pont in the states of Illinois, Alabama, Washington, and New Jersey, in the fields of explosives, nucleonics and plastics. At present he is serving on the Public Relations Committee of A.I. Ch.E. and is vice-chairman of its Terre Haute Section. A Ph.D. from Purdue in 1952, Dr. Bankoff is working this summer as principal development engineer, Reactor Experimental Engineering Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Charles F. Hauck has been advanced to the position of sales manager, chemical plants division, Blaw-Knox Co. He joined the company in 1951 as manager of sales promotion of the chemical plants division, and was later advanced to assistant sales manager.

J. S. Wolff, formerly Washington representative, B. F. Goodrich Chemical Co., will shift into the agricultural chemical staff representative position, relocating in Cleveland. After receiving his B.S. in chemical engineering from Carnegie Institute of Technology in 1940, he served in the Chemical Warfare Service for five years before going to BFG in 1946 as a development engineer. He joined the sales department in 1947, and in 1951 was made the company's representative in Washington, D. C.

Robert A. Brobst, formerly with the Waterloo Dehydrating Co., is now assistant chemical engineer, chemical engineering division at Midwest Research Institute. **Charles E. Mumma,** formerly with the Tennessee Valley Authority, is associate chemical engineer with the same company.

It has been announced that **Laurence C. Johnston** has become vice-president of Brown Fintube Co., Elyria, Ohio. He will continue to manage sales of heat exchangers and all other equipment in the Eastern territory, with offices in New York. Johnston joined the company as Eastern district sales manager in 1949, after service with Process Engineering, Inc., and Patterson-Kelley Co. He graduated from the University of Michigan in 1930 in mechanical engineering.

Charles R. Fishback has joined the staff of the Whiting Research Laboratories of Standard Oil Company (Ind.). Mr. Fishback is a chemical engineering graduate of Purdue University.

Vance O. Bonnichsen has been transferred to Chemstrand's nylon plant under construction near Pensacola. He had been in Chemstrand's central engineering section since he joined the company in July, 1951. Mr. Bonnichsen has been assigned as a group leader in the supervision of a chemical intermediates area. Mr. Bonnichsen holds a B.S. degree from Iowa State College and an M.S. degree from Texas A. & M.

The appointment of **Edward M. Redding** as director of research has recently been announced by The Sharples Corp. Research Laboratories, Bridgeport, Pa. Prior to his position with Sharples, Dr. Redding was with the Charles F. Kettering Foundation, Dayton, Ohio, where he was director of research since 1948. The principal research efforts under his direction were in the fields of solar energy and photosynthesis. Dr. Redding received a D.S. in chemical engineering from the Massachusetts Institute of Technology in 1942. During World War II was in the power plant design branch, U. S. Navy Bureau of Aeronautics. After the war Dr. Redding was assistant director of the Aerophysics Lab., North American Aviation, Los Angeles. After a short period of research on the Lexington Project at M.I.T., he was appointed director of research of the Charles F. Kettering Foundation.

(More News About People on page 77)

BAMAG

NITRIC ACID MANUFACTURERS

Would you consider a yearly saving in operating costs in excess of $100,000?

Then be sure to consult GIDCO concerning the BAMAG *nitric acid* process before making a decision on your new plant.

BAMAG OFFERS:

1. **Ammonia conversion at atmospheric pressure for higher yields and lower catalyst losses**
2. **Absorption with or without pressure as required**
3. **Energy recovery in steam and tailgas turbines**
4. **Simple and automatic operation**

Consult without obligation

GENERAL INDUSTRIAL DEVELOPMENT CORP.

270 Park Ave., New York 17, N. Y.

BAMAG-MEGUIN

270 PARK AVE. • NEW YORK 17, N. Y.

CLASSIFIED SECTION

Advertisements in the Classified Section of Chemical Engineering Progress are payable in advance, and are placed at 15c a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line insertion (about 36 words) free of charge per year. More than one insertion to members will be made at half rates. In using the Classified Section of Chemical Engineering Progress it is agreed by prospective employers and employees that all communications will be acknowledged, and the service is made available on that condition. Boxed advertisements are available at $15 per inch. Size of type may be specified by advertiser. In answering advertisements all box numbers should be addressed care of Chemical Engineering Progress, Classified Section, 120 East 41st Street, New York 17, N. Y. Telephone ORegon 9-1560. Advertisements for this section should be in the editorial offices the 15th of the month preceding the issue in which it is to appear.

SITUATIONS OPEN

UNIVERSITY OF TORONTO

Department of Chemical Engineering and Applied Chemistry

Lecturer. Inquiries are invited from graduates in chemistry or chemical engineering with Ph.D. or equivalent experience. Opportunity for advancement to professorial grade.

CHEMICAL ENGINEER

For nation-wide food manufacturer—engineering research and development. Four years' experience in one or more of the unit operations, preferably filtration, heat transfer, refrigeration, or drying. Salary commensurate. Applications confidential. Submit résumé of experience, education and salary desired. Box 17-7.

GRADUATE CHEMICAL ENGINEER OR CHEMIST

with training in statistical methods which should include courses in analysis of variance, mathematical statistics, theory of sampling, etc. Previous industrial experience desirable but not necessary. Large chemical company located in Southwest.

Salary open.

Box 4-7

CHEMICAL ENGINEER

Age to 30; preferably one to two years' general plant experience; for process control work in progressive chemical plant in the Louisville, Kentucky, area.

Give résumé in first letter.

Box 2-7

MANUFACTURERS AGENTS knowing the chemical process industries and or pneumatics wanted by well established filter manufacturer with representatives in twenty-five cities. Require alert aggressive representation. Expanding activities in the following areas: Baltimore, Dallas-Ft. Worth, Indianapolis, Milwaukee, Minneapolis-St. Paul, New Orleans, Toledo. Some other territories open also. Inquire R. P. Adams Co., Inc., Box 145, Kenmore Station, Buffalo 17, N. Y.

INSTRUCTORSHIP OR ASSISTANT PROFESSORSHIP — Permanent. Salary open, dependent on qualifications. Address inquiries to: Chairman, Department of Chemical Engineering, University of New Mexico, Albuquerque, N. M.

CHEMISTS
CHEMICAL ENGINEERS

Ph.D. — M.S. — B.S.

In chemistry or chemical engineering.

For fundamental research, for process and equipment development. Large Midwestern manufacturer of molding compounds, coating resins, adhesives, and silicones. Submit complete résumé and salary requirements. Box 18-7.

SITUATIONS WANTED

A.I.Ch.E. Members

ENGINEERING MANAGER AVAILABLE — Chemical engineer with background in complete plant design and preparation and analysis of budgets for existing and proposed industrial installations. Bulk of previous experience in detergent, pharmaceutical, and organic chemicals fields. Metropolitan N. Y. preferred. Box 1-7.

JUNIOR EXECUTIVE—Position wanted by B.S.Ch.E. age 28. Six years' diversified design, operations, and development experience. Wish to use engineering background to solve management and business problems. Box 3-7.

CHEMICAL ENGINEER—Two credits short of M.Ch.E., B.S. in 1950. Desire a position with a future in production or development. One year research fellowship in plastics. Age 27, married, veteran. Box 5-7.

SALES ENGINEER—B.S.Ch.E. Age 35. Experienced in plant operation and industrial selling. Desire to represent one additional company in Alabama and adjacent area. Prefer company now doing business in territory and anxious to expand sales. Box 6-7.

SALES—Live wire chemical engineer, bored with research and development, desires challenging opportunity in chemical or process equipment sales. Six years' diversified experience in organic coatings, explosives and allied chemicals. B.Ch.E. Age 28, single, personable, good appearance. Box 7-7.

CHEMICAL ENGINEER—Age 31. Six years process development and pilot plant supervision in synthetic organic chemicals. A.I.Ch.E., Active; A.C.S., Senior; N.A.F., Professional Registration. Married, veteran. Box 8-7.

CHEMICAL ENGINEER ADMINISTRATOR—Twenty years' experience inorganic chemical process design and operation, economic evaluation, equipment selection. Last twelve years' experience titanium dioxide manufacture. Desire responsible position in process development or plant administration. Box 9-7.

CHEMICAL ENGINEER—Age 36. Thirteen years' experience research and development, project engineering, production supervision in ammonia, fertilizers, chlorine, fine organics. Present position of staff level, salary $10,000. Outstanding references. Prefer West or Midwest. Box 10-7.

CHEMICAL ENGINEER — B.S.Ch.E., Illinois Institute of Technology, 1941. Experience in technical supervision of pilot plants, design, program planning, and correlation of data. Desire position in process or project engineering, or research and development. Box 11-7.

CHEMICAL ENGINEER—Age 25. Personable. Two years sales correspondence, cost estimation, process design, equipment specification. Some business and sales training. Desire sales or application research leading to sales in southern California. Box 12-7.

CHEMICAL PROCESS ENGINEER—B.S. 1941. Desire morning work in New York area to permit study for advanced degree afternoons and evenings. Experienced in economic evaluation, design, and operation of nitrogenous fertilizer, refining, natural gasoline, and petrochemical plants. If interested, please write for a résumé. Box 13-7.

CHEMICAL ENGINEER — B.S. 1950 New Hampshire. Age 26, family. Three years' supervision, pilot plant, design and development experience. Desire development work with progressive chemical company. Box 14-7.

CHEMICAL ENGINEER—B.S.Ch.E. Age 26, married, veteran. Not member of reserves. Experienced in research and development problems. Desire position in process control and technical service. Prefer New England location. Box 15-7.

CHEMICAL ENGINEER—B.S. Eight years' diversified experience. Desire position in pilot plant, development or production with medium-sized company in New York City area. Age 32, married. Box 19-7.

CHEMICAL ENGINEER — Registered professional engineer. Age 43. Twenty-four years' experience in production and plant design. At present am a senior engineer in charge of seven project engineers for a pharmaceutical and biological firm. A position of chief or assistant chief engineer or equivalent is desired. Box 20-7.

Nonmembers

CHEMICAL ENGINEER—B.S.Ch.E. 1949, B.S. Business Administration (night classes). Age 29, married, high scholastic record. Now employed (since 1949) as project engineer by medium-sized chemical firm. Desire position with advancement possibilities in southern California. Box 16-7.

PEOPLE

(*Continued from page 75*)

Ray H. Boundy, a Dow Chemical Co. director and director of research for the company since 1952, has been appointed a vice-president of the company. Dr. Boundy has been with Dow since 1926 and has been closely associated with the company's developments in the fields of hydrocarbons and plastics.

The appointment of **Edwin Frederic Pike** of New York as director of its chemical engineering department, has been announced by Giffels & Vallet, Inc., L. Rossetti, associated engineers and architects, of Detroit. Dr. Pike takes over his new position following completion of a survey on the chemical potentials of Ireland for the government of that country. His business experience has been in executive positions and consultation services for Wallace Clark & Co., Smidas Co., American Home Products Corp., Gelatin Products Corp., Armour and Co., A. E. Staley Manufacturing Co., and the Kieckhefer Container Co.

S. C. Doshi, formerly assistant plant superintendent, caustic soda plant, D.C.M. Chemical Works, Delhi, India, is now associated with the Indian Aluminum Co., Ltd., at its Kalwa Works.

William R. Veazey, long identified with research and administrative activities of The Dow Chemical Co., Midland, Mich., has retired after thirty-seven years of service, including twenty-six years as a member of the board of directors. Starting his career in the teaching profession at Case School of Applied Science, now Case Institute of Technology, in 1907, he became a consultant to Dow in 1916, continuing in this capacity until 1936 when he resigned his professorship at Case to become a full-time Dow employee. In 1949 he became chairman of the executive research committee, and later a research consultant.

HYDROCARBON
PANAFLEX ...EP-1
PLASTICIZERS

A LOW COST PLASTICIZER OIL
for Rubber Compounding

PROPERTIES
Low Specific Gravity — Dark Viscous Liquid
Extremely High Boiling

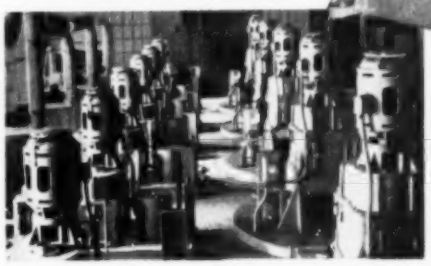
FOR
Improved Processing — Improved Electrical Characteristics
Minimum Effect on Cure
Extending Vulcanizates — Better Tear Resistance

EXCELLENT COMPATIBILITY WITH
GRS Rubbers—All Types — Buna N Type Rubbers
Neoprene Rubber

AVAILABILITY
Basic Producer — Tank Car or Drums
Warehouse Distribution

PAN AMERICAN Chemicals
PAN AMERICAN CHEMICALS DIVISION
Pan American Refining Corp
122 EAST 42ND STREET · NEW YORK 17, N. Y.

PACIFIC-WESTERN
Agitator Drives..
Built for years of economical, heavy-duty service!



Pacific-Western TV-64, vertical triple reduction drive unit

Eleven double reduction Pacific-Western vertical agitator drives with 75 HP motors occupy minimum floor area in installation with capacity of 450 tons of bleached pulp per day.

Available in single, double and triple units
Write for Booklet No. 5308
Address your request to nearest Pacific-Western office.

Check these outstanding features...

- Vertical electric drive saves space...
- Full range of ratios, from 12 to 1 through 300 to 1 with DV or TV units...
- Low speed shafts equipped with heavy duty tapered roller bearings eliminate need for separate thrust bearings...
- Lubricating systems especially designed to meet every application...
- Scavenging pump systems eliminate all possibility of oil leakage around low speed shaft...
- Modern vertical drives are considerably less expensive than old style right-angle drives...
- Simple, compact design and construction reduces installation and maintenance cost...

...Complete Engineering Service Available...

WESTERN GEAR WORKS
Manufacturers of PACIFIC-WESTERN Gear Products
Plants: Seattle, San Francisco, Belmont (S. F. Peninsula), Lynwood (Los Angeles County), Houston
Pacific Gear & Tool Works

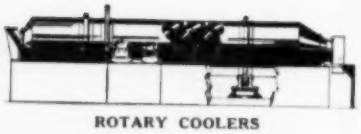
Write, Wire or Phone
WESTERN GEAR WORKS
417 Ninth Ave., So.,
Seattle, Washington
. . . Main 0062

DOUBLE SHELL DRYERS

SINGLE SHELL DRYERS

RUGGLES-COLES
CONTINUOUS
ROTARY
DRYERS,
KILNS,
AND
COOLERS

ROTARY KILNS



ROTARY COOLERS

Ask for Bulletin 16-D-40 which describes the entire Ruggles-Coles line

HARDINGE
COMPANY, INCORPORATED
YORK, PENNSYLVANIA · 240 Arch St. · Main Office and Works
New York · Toronto · Chicago · Hibbing · Houston · Salt Lake City · San Francisco

ASSISTANT DIRECTORS OF MONSANTO NAMED

The appointments of four staff engineers to the positions of assistant directors of Monsanto Chemical Co.'s general development department were recently announced. Promoted to the new posts are the following: Robert H. Kittner, C. Rogers McCullough, David S. Weddell and Robert York, Jr., all of St. Louis. All four have been staff members of the general development department.

Kittner joined Monsanto in July, 1951, after having been production manager of the Industrial Rayon Corporation of Cleveland. He received a chemical engineering degree from Columbia University (1929). Previously he had been vice-president in charge of the chemicals division of the Glenn L. Martin Co., Baltimore, Md.

McCullough, who has been identified with atomic energy power projects, received an A.B. degree from Swarthmore College (1921) and M.S. and Ph.D. degrees from M.I.T. (1922 and 1928). He has been with Monsanto since 1928, serving as a research group leader and manager of research projects.

Weddell joined the company in 1941 after he had received an Sc.D. degree in chemical engineering from M.I.T. He had been graduated from Pennsylvania State College (1938) with a B.S. degree in the same field. In addition to his general development department assignments, he also has served the central research department, the phosphate division research department and the development department of the Western division. He will serve as administrative assistant in development matters.

York received B.S. and M.S. degrees from the University of Tennessee (1933 and 1934) and an Sc.D. degree from M.I.T. (1938). Prior to his association with Monsanto, he was associate professor of chemical engineering at Carnegie Institute of Technology and practiced as a consultant. He joined Monsanto in 1944, while on a leave of absence from Carnegie Institute. He rejoined the company's general engineering Department in 1947 as a chemical engineering specialist and was transferred to the general development department late in 1948.

William M. Herring has joined the staff of the Whiting Research Laboratories of Standard Oil Co. (Ind.). Dr. Herring did his undergraduate work at Virginia Polytechnic Institute and received his Ph.D. degree in chemical engineering at the Univ. of Wisconsin.

C. John Setzer, research chemical engineer in the general process section, Chemstrand Corp., Decatur, Ala., has been assigned to the research and development department. He was formerly an instructor at Ohio State University and received a Ph.D. degree in chemical engineering from that institution.

The Anthracite Equipment Corp., Wilkes-Barre, Pa., has announced the appointment of **George A. Love,** formerly with Oliver United Filters, Inc., as sales manager for AnthraAid, new carbonaceous filter-aid.

Necrology

Harry McCormack, technical editorial director of Food Processing and Chemical Processing, died on June 8. For thirty-eight years he had served as director of the chemical engineering department of Illinois Institute of Technology and the Armour Research Foundation. He held degrees from Drake University and the Illinois Institute of Technology. In October, 1951, the Putman Publishing Co. established an annual food-processing fellowship in his honor. As that company's technical editorial director, he was responsible for investigating and directing preparation of technical information for the food and chemical fields. Professor McCormack was co-author of the book "Application of Chemical Engineering." He was 76 years old.

LaVerne E. Cheyney, 42, manager, contract research department, Minnesota Mining & Manufacturing Co., Detroit, Mich. Mr. Cheyney served as an analytical chemist at B. F. Goodrich; research chemist at National Aniline Division, Allied Chemical and Dye Corp.; research chemist, section leader at Goodyear Tire and Rubber Co.; assistant professor at University of Akron; supervisor, Battelle Memorial Institute; research director, Pollock Paper Corp., and development supervisor, Minnesota Mining & Manufacturing Co. He received a M.S. from the University of Pennsylvania and a Ph.D. from Ohio State University in 1938.

Herbert Philipp, 73, retired chemical engineer. Dr. Philipp was born in London, England, educated at Zurich Polytechnicschule and received a doctorate there in 1901. He was with the Solvay Process Division, Allied Chemical and Dye Corp. in Syracuse, New York, at the time of his retirement in 1950.

Richard A. Crawford, associated with B. F. Goodrich Co., Akron, Ohio, Dr. Crawford first became associated with Goodrich as a research chemist in 1924 and at the time of his death was director of rubber research. He received his B.A., M.S., and Ph.D. from Ohio State University.

INDEX OF ADVERTISERS

	Page
A	
Abbe, Inc., Paul O.	58
Adams Co., Inc., R. P.	10
Aldrich Pump Co.	59
American Pulverizer Co.	73
Artisan Metal Products, Inc.	10
B	
Babcock & Wilcox Co., Tubular Products Div.	8
Baker Perkins, Inc.	14
Barnstead Still & Sterilizer Co.	50
Bowen Engineering, Inc.	49
C	
Carbide & Carbon Chemicals Co., A Division of Union Carbide and Carbon Corp.,	*Inside Front Cover*
Condenser Service & Engineering Co., Inc.	52
Corning Glass Works	34, 35
Crane Company	65
Croll-Reynolds Co., Inc.	79
D	
Delrac Corporation	54
Dorr Company, The	61
Dow Chemical Co.	9
Dow Corning Corporation	71
Duraloy Company	67
E	
Eco Engineering Co.	64
Eimco Corporation	19
F	
Falls Industries, Inc.	66
Filtration Engineers, Inc.	68
Fluor Corp., Ltd.	40
Foxboro Co.	21
G	
General American Transportation Corp.	332
General Industrial Development Corp.	75
Girdler Corp.	15
Great Lakes Carbon Corp., Electrode Division	11
Gump Company, B. F.	3
H	
Hardinge Co., Inc.	78
Haveg Corporation	69
Hilliard Corporation	4
Hills-McCanna Co.	32
Hofman Laboratories, Inc.	13
Hudson Engineering Corp.	7
I	
International Nickel Co., Inc.	53
J	
Johns-Manville	51
L	
Lawrence Pumps, Inc.	12
Little, Inc., Arthur D.	31
Louisville Drying Machinery Unit, General American Transportation Corp.	332
M	
Metal Textile Corp.	71
Milton Roy Company	*Inside Back Cover*
Minneapolis-Honeywell Regulator Co.	26, 27
Mixing Equipment Co., Inc.	*Back Cover*
N	
National Carbon Co., A Division of Union Carbide and Carbon Corp.	37
Nicholson & Co., W. H.	73
O	
Okadee Company	60
P	
Pacific Gear & Tool Works	77
Pan American Chemicals Div., Pan American Refining Corp.	77
Pfaudler Company, The	16
Posey Iron Works, Inc.	5
R	
Read Standard Corp.	6
Republic Flow Meters Co.	55
Rockwell Manufacturing Co.	23, 24
Rohm & Haas Co.	39
S	
Sargent's Sons Corp., C. G.	63
Sharples Corp., The	57
Sparkler Mfg. Co.	25
Spraying Systems Co.	52
Stahmer Shoe Co.	79
Struthers Wells Corp.	28
U	
Union Carbide and Carbon Corp., Carbide and Carbon Chemicals Co.,	*Inside Front Cover*
National Carbon Co.	37
United States Gasket Co.	33
W	
Western Gear Works	77

Advertising Offices

New York 17—Lansing T. Dupree, Adv. Mgr.; Paul A. Jolcuvar, Dist. Mgr.; 120 E. 41st St., Oregon 9-1560.

Chicago 4—Richard R. Quinn, Dist. Mgr., 20 E. Jackson Blvd., Room 800, Webster 9-2225.

Cleveland 15—Douglas H. Boynton, Dist. Mgr., 1836 Euclid Ave., Superior 1-3315.

Pasadena 1—Richard P. McKey, Dist. Mgr., 465 East Union St., Ryan 1-8779.

STAHMER

Wood Sole SHOES

Chemical Plant Shoe Style 1230

for the CHEMICAL INDUSTRY

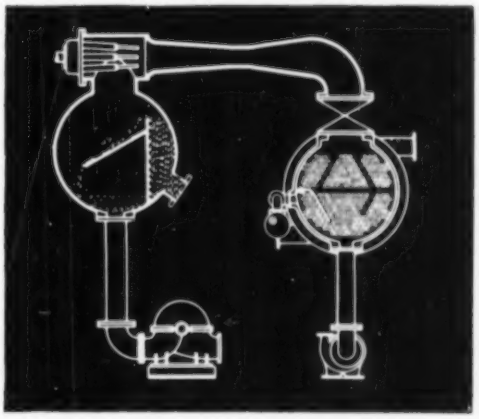
Resistant to chemicals, acids, salts, oils, water and heat. Superior to leather or rubber in many operations; less slipping in wet processing. Cost less—wear longer. Sizes for men and women: 5 to 12. Steel safety toe optional.

Send for Catalog

STAHMER SHOE CO.

Davenport 10, Iowa

Established 1900



Water cools itself with a C-R Chill-Vactor

A Chill-Vactor is a three-stage steam-jet vacuum unit which serves to flash-cool water and certain other liquids through temperatures down to 32° F. No chemical refrigerant is used. There are no moving parts. Water literally "cools itself" by partial evaporation at high vacuum. Vacuum refrigeration is usually less expensive than mechanical refrigeration in first cost as well as operating cost.

Chill-Vactors are producing chilled water in industrial plants throughout the world. They are cooling chemical solutions, fruit juices, milk, whiskey mash, etc. Bread and other baked goods have been vacuum cooled successfully for years. Other products, such as lettuce, spinach, celery and other leafy vegetables, are being cooled to temperatures around 33° F. in quantities up to 200 cars a day.

The Chill-Vactor is only one type of steam-jet evactor manufactured by Croll-Reynolds. Let our technical staff help you with any or all of YOUR vacuum problems.

CROLL-REYNOLDS

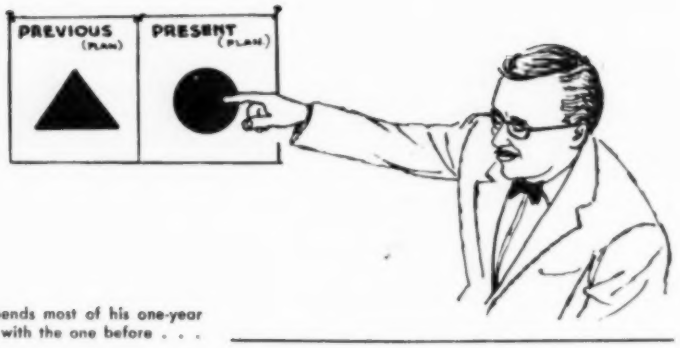
CROLL-REYNOLDS CO., INC.

Main Office: 751 Central Avenue, Westfield, New Jersey

New York Office: 17 John Street, New York 38, N. Y.

CHILL-VACTORS • STEAM JET EVACTORS • CONDENSING EQUIPMENT

THE PRESIDENT SAYS



. . . it sometimes happens that a new president spends most of his one-year term formulating a program which does not dovetail with the one before . . .

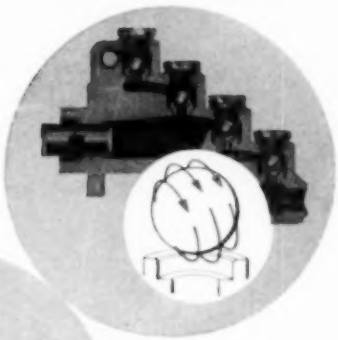
In the June column I mentioned the way Vice-President Kirkbride is working with me to chart a program for Institute accomplishment running through 1954 and our intention to bring into this scheme the man elected Vice-President for next year. We are confident that this arrangement for orderly planning and for continuity and consistency will prove worth while. In groups such as ours, it sometimes happens that a new president spends most of his one-year term formulating a program which does not dovetail with the one before and which will not be integrated with the one to come. Naturally, nothing really constructive will get done under these circumstances and we want to avoid such an error.

Short-range planning can certainly be useful but it is desirable to consider also the relatively long-range picture. Only by achieving a vision of the probable future development of A.I.Ch.E. can we feel real confidence in the validity of the decisions we must make from month to month. This idea was in the mind of Frank Curtis when he became President in 1949. He promptly sold Council on the establishment of a "Committee on the Future of the Institute." This committee has passed through several metamorphoses in the intervening period, and there has been the usual difficulty in reducing a quite nebulous matter to a practical basis for concrete action. I say "usual difficulty" because it has been my experience that any project involving long-range speculation stays in the hazy, vague stage for a considerable period in spite of all attempts to the contrary. In many cases the project *never* emerges from this stage.

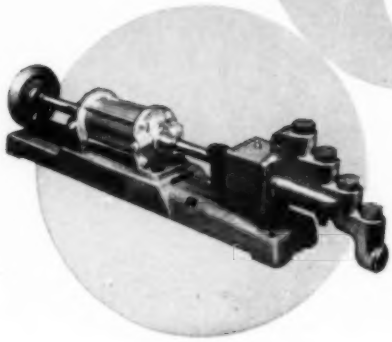
Our project *has* emerged. George Holbrook is now heading up the work on the "Future of the Institute" and is ably assisted by Jack Perry, Chaplin Tyler, Norman Krase and Kenneth Kettenring. This fivesome is in a position to get together frequently and as these men find the need, they will call on Institute members here and there for help and advice. Their plan is to work out a projection of the Institute's potential growth and development *through 1975*. To accomplish this, they will try to identify all the vital factors affecting growth, plus all information which needs to be considered in relation to each factor. One of the important tasks is to make estimates of growth of membership, income, and necessary expenditures. They must speculate about our publishing needs, and what new journals and other publications we are likely to have to launch in the future. These considerations will influence such questions as the paid staff, office space, and physical facilities. We can be much stronger in every way, including financially, if we do a good job of anticipating our needs and not have to make important decisions on the basis of expediency or without understanding the true nature of the problems involved.

It is entirely possible that many who are reading this are hearing about the project for the first time. I can not feel that this is good. Any task force such as the one mentioned surely deserves a certain amount of privacy and a chance to function quietly without annoying though well-intentioned interference, but I believe we should periodically tell our members what is going on. While some privacy is essential, we want to make it possible for interested members to submit their ideas.

W. T. Nichols



Basic design simplicity of the *exclusive* Milton Roy liquid end step-valve assures high and reproducible volumetric efficiency. Self-cleaning *double* ball-checks spin any lodged particle free, are non-clogging, seat positively.



One-Half of One Per Cent Accuracy with this Milton Roy Pump

CONTROLLED VOLUME PUMPING

INSTRUMENTATION

PROCESS CONTROL SYSTEMS

BLENDING AND FORMULATING

On The Job in a leading processing plant, two of these air-powered controlled volume pumps meter deionized water solution from a chemical proportioning system to a key production process. Data obtained from *one full year* of operation showed a pumping accuracy within ½ of one per cent!

This is a typical Milton Roy Pump—one of many types of air-powered or motor-driven positive displacement pumps—in daily use in hundreds of similar operations. In *chemical processing*, for example, they're used in fermentation, pH control, hydrogenation of fatty acids. In the *textile and paper fields*, for resin impregnations, peroxide saturates, finish liquors. In *metals and mining*, for plating solution recovery, ore flotation, diatomaceous earth slurry handling. Wide as industry itself, the application of these pumps gives dollar savings not only in accuracy, but in longer service life and man-hours saved. These pumps meter practically any liquid in capacities from 3 milliliters per *hour* to 45 gallons per *minute* against pressures ranging to 25,000 pounds per square inch. They are available as single or multiple units, or as component parts of complete chemical feed and control systems.

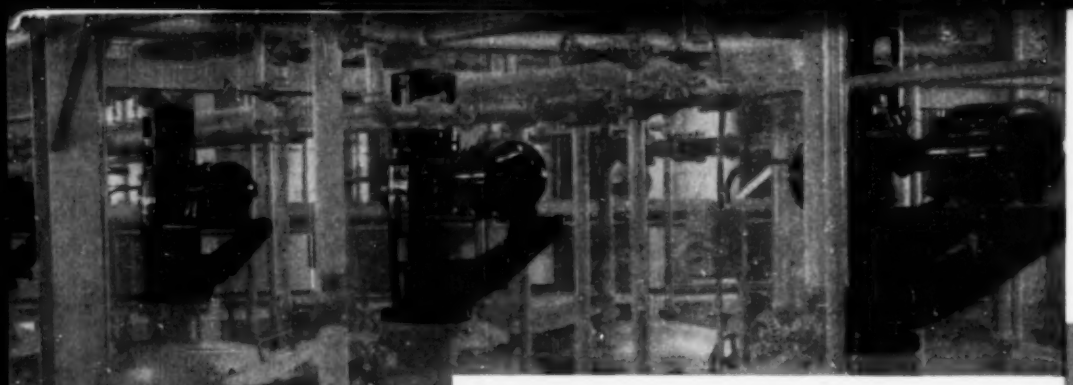
Bulletin No. 351 gives you facts on Milton Roy **Air-Powered** Controlled Volume Pumps and their application. Write, now, for your **free** copy.

Engineering Representatives in the United States, Canada, Mexico, Europe, Asia, South America and Africa.

MILTON Roy COMPANY

Manufacturing Engineers • 1379 E. MERMAID LANE • PHILA. 18, PA

CONTROLLED VOLUME PUMPS AND AUTOMATIC CHEMICAL FEED SYSTEMS



LIGHTNIN SERIES TE Mixers on special lubricant production. These units supplied for open tanks or closed pressure vessels, in sizes from 1 to 500 HP.

How you can be sure of efficient fluid mixing

Why experiment, when you can be sure?

If the operation involves fluid mixing, you can have *guaranteed results,* with LIGHTNIN Mixers.

The LIGHTNIN guarantee protects you fully on any fluid mixing, blending, or circulating operation.

It protects you fully even on such operations as:

heat transfer	washing
gas dispersion	dissolving
solids suspension	crystal size control

All you do is tell us a few facts about the materials, the tank or vessel, the end results you want, and how quickly you want them. We do the rest—and guarantee you'll be satisfied.

This wouldn't be possible without four things:

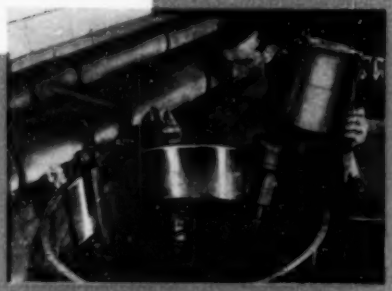
Really wide experience in serving the process industries

Most advanced mixing technology in the field

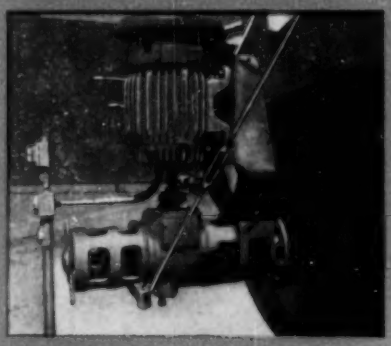
A force of over 125 experienced mixing engineers at the factory and in 26 major industrial sections throughout the country

Fullest selection of *field-proved* equipment to meet every fluid mixing requirement

We think we have all four. We're sure enough to bet on it. When can we get together?

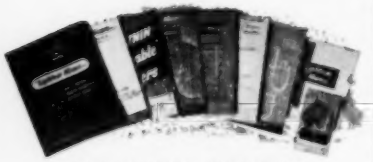


LIGHTNIN PORTABLE Mixers are used everywhere to do hundreds of mixing jobs. Thirty models to choose from. Sizes ⅙ to 3 HP.



LIGHTNIN SERIES SE Mixers, for large tanks, offer new easy repacking; choice of stuffing boxes or mechanical seals. Sizes 1 to 25 HP.

Lightnin® Mixers



GET THESE HELPFUL LIGHTNIN CATALOGS

This library of mixing information is yours for the asking. Catalogs contain helpful data on impeller selection; sizing; best type of vessel; valuable installation and operating hints; complete description of LIGHTNIN Mixers.

MIXCO fluid mixing specialists

MIXING EQUIPMENT Co., Inc.

199 Mt. Read Blvd., Rochester 11, N. Y.

In Canada: William & J. G. Greey, Ltd., Toronto 1, Ont.

- ☐ DH-50 Laboratory Mixers
- ☐ B-75 Portable Mixers (electric and air driven)
- ☐ B-102 Top Entering Mixers (turbine and paddle types)
- ☐ B-103 Top Entering Mixers (propeller types)
- ☐ B-104 Side Entering Mixers
- ☐ B-105 Condensed Catalog (complete line)
- ☐ B-107 Mixing Data Sheet

Please send me the catalogs checked at left.

Name _____ Title _____

Company _____

Address _____

City _____ State _____